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DEPARTMENT OF MINES

HON. ARTHUR MEIGHEN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

WILLIAM MCINNES, DIRECTOR.

Summary Report, 1919, Part B

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SUMMARY REPORT, 1919, PART B.

THE BRITISH COLUMBIA OFFICE.

The existence of this office has become so well known to the general public interested in mining throughout the province that greater and greater demands are being made on the staff as time goes by for information on subjects relating to economic and general geological problems.

The office is visited daily by numbers of prospectors, mining engineers, and others, who desire maps, reports, or such other unpublished information as the members of the staff are able to supply from their personal knowledge of a particular subject.

During the past year, all these demands have been satisfactorily met and much has been accomplished in the public interest by the Geological Survey, that could not otherwise have been done if this office had not been established.

There has also been a close co-operation and co-ordination with the work of the Provincial Department of Mines, with the result that unnecessary overlapping has been avoided and greater efficiency obtained.

The work of the office has increased to such an extent that it requires the almost constant attendance of the officer in charge throughout the whole year. To such an extent is this so that no extensive programme of field work could be undertaken in 1919 by that officer and only a very small proportion of the field season could be devoted to outside work.

Besides the distribution of maps and reports and other geological information numerous determinations have been made of the rock and mineral specimens submitted to the office.

Owing to the lack of adequate facilities for carrying out this phase of the work complete results could not always be obtained and many samples had, necessarily, to be sent to Ottawa for determination.

The equipping of the office with an excellent modern metallographic microscope has been a great aid to the staff in making mineral determinations, but the addition to the equipment of some chemical apparatus and re-agents would greatly enlarge the field of usefulness of the office.

A record of the names of people calling at the office throughout the year shows that the number ranges from three to twelve or fifteen daily.

EXPLORATIONS IN THE OGILVIE RANGE, YUKON.

By W. E. Cockfield.

INTRODUCTION.

The field season of 1919 was spent largely in the exploration of a portion of the Ogilvie range. The discovery of galena deposits at Mayo, on the outskirts of the range, and on Twelvemile river within the range itself, and the reports of copper by prospectors who had made trips across the range, made it desirable that some knowledge of the intervening country should be obtained in order to stimulate prospecting. Owing to the inaccessibility of the district and the fact that no base maps of the area were obtainable, much of the time available was necessarily spent in preliminary work including triangulation for control and ordinary mapping.

The route selected was by way of the valley of the North Fork of Klondike river. This valley and that of Twelvemile river presented the most feasible routes to the height of land, and as some knowledge of the geology of Twelvemile river[1] had already been obtained it was considered desirable to travel by the North Fork.

A rapid triangulation for purposes of control was carried from Dawson to the height of land, following the valley of the North Fork of Klondike river. From the mouth of the North Fork details were filled in by plane-table sketching, and in this way a map of the drainage with sketched contours showing relief was obtained. No attempt was made to make an accurate topographic map. E. Beltz and E. Hughes acted as assistants and performed their duties in a capable and satisfactory manner.

TOPOGRAPHY.

The Ogilvie range may be considered as a spur of Mackenzie mountains, extending from near the headwaters of Stewart river to the Yukon, near the crossing of the 141st meridian. Considered as a whole the range has a rugged and mountainous aspect and consists of long, branching, knife-edge crests, with sharp and often precipitous peaks, separated by deeply cut valleys. The average relief of the district is about 3,500 to 4,000 feet. Beyond a somewhat general accordance of summit levels the range gives no evidence of ever having been planated, and probably was an upland tract at the time of the planation and subsequent uplift of the Yukon plateau.

The Yukon plateau is separated from the mountain province by a belt of lowland or by an old drainage channel which cuts diagonally across the present drainage courses. It has a width of from 10 to 15 miles and is floored by sands and gravels with a thickness of 600 to 700 feet. These are referred by McConnell to the late Tertiary.[2]

Numerous evidences of glaciation exist, especially in the upper reaches of the valleys which frequently terminate in cirques. Small lakes with rock-rimmed basins are also numerous in the higher portions of the valleys. The glaciation was local, and was apparently more intense on the northern slopes. As a result of post-glacial changes the North Fork has in several places cut deep trenches or canyons both in unconsolidated material and in bedrock and has overdeepened portions of the channel, with the result that tributary streams are depositing wide flats of gravel over which the streams flow as braided watercourses. These have a tendency to overflow in winter and thick masses of ice are formed on the flats and remain for the greater part of the summer.

The valley of the North Fork of Klondike river offers a low, flat pass into Blackstone river. The elevation of this pass is slightly less than 4,000 feet; and at the summit the valley is so flat and swampy that it is difficult to tell where the actual divide occurs.

GENERAL GEOLOGY.

The part of the Ogilvie range studied during the past summer is underlain by a thick series of sediments of undetermined age, composed of cherts, quartzites and black slates, conglomerates, and red and green slates. The quartzites and black slates are intimately associated, as are also the red and green slates, the red colour being apparently due to oxidation. There is no evidence to show that these rocks are other than of one general age, and consequently they are grouped together. They strike in a general northeasterly direction, and dip generally to the northwest, although many minor folds occur. The series continues to the northwest as far as the valley of Twelvemile river.[3] The sediments are cut by dykes and sills and other small bodies

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[1] Cockfield, W. E., "The silver-lead deposits of the Twelvemile area," Geol. Surv., Can., Sum. Rept., 1918, pp. 15B-17B.

[2] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. XIV, pp. 24B-25B.

[3] Cockfield, W. E., "The silver-lead deposits of the Twelvemile area," Geol. Surv., Can., Sum. Rept., 1918, pp. 15B-17B.

of igneous rock including granite porphyry, diorite, diabase, and basalt. Sills form an important feature of the geology of the district. They are usually composed of diabase, and follow the strike and dip of the strata for long distances; and, in addition, govern the topography to a great extent, as owing to superior resistance they form the crests of many of the ridges and peaks.

Mineral Resources.

No deposits of minerals of present economic value are known within the area actually mapped during the past season. Large deposits of antimony are reported to occur at the head of Fish creek, and placer copper has been reported from the head of Blackstone river; but, on account of a prematurely early fall of snow which rendered it almost impossible to obtain information with regard to prospects where no underground work had been done and the urgency of a visit to the Mayo area before the close of the season, these occurrences were not seen.

In conclusion it may be pointed out that, as geological conditions are similar to those in the valley of Twelvemile river, the district offers some inducements to the prospector. Work, however, should be confined to limited areas in the vicinity of bodies of igneous rocks.

MAYO AREA, YUKON.

By W. E. Cockfield.

INTRODUCTION.

Two weeks at the end of the field season were spent in the Mayo area, which, owing to the recent discoveries of argentiferous galena, appears to be at this time the most promising camp in central Yukon. No lengthy description of the geology and topography of this region need be given, as reports on the geology and economic features have already been published[1]; and, owing to the short time available for the visit, attention was paid only to deposits of argentiferous galena. The newly discovered properties on Keno hill were examined, as well as the properties on Lookout mountain, Rambler hill, and mount Cameron.

DEVELOPMENT OF THE PROPERTIES.

Keno Hill.

Keno hill lies between the head of Lightning creek, a tributary to Duncan creek, and Christal creek, at a distance of about 40 miles from Mayo by wagon road. The discovery of galena carrying high values in silver was made by Louis Beauvette in July 1918. A stampede to the hill took place, and upwards of a hundred claims were staked and recorded in the vicinity. Many of these have mineral showings as float, but as time did not permit of an extended examination, attention was confined largely to the original discovery and adjacent claims.

The rock exposed on Keno hill consists of gneissoid quartzites, quartz-mica schists, and mica schists belonging evidently to the series of sedimentary schists and gneisses known as the Nasina series. These are cut by a dyke of greenstone which has also been sheared to a considerable extent. This dyke, owing to differential erosion,

[1] Keele, J., "Upper Stewart River region," Geol. Surv., Can., Ann. Rept., vol. XVI, pt. C.
Cairnes, D.D., Geol. Surv., Can., Sum. Rept., 1915, pp. 10-34.
Cockfield, W. E., Geol. Surv., Can., Sum. Rept., 1918, pp. 1B-15B.

projects about 50 feet above the surrounding rocks and forms an important topographic feature. It extends in a general east-west direction and forms the top of the ridge known as Keno hill, the summit of which is 6,400 feet above sea-level. The greater part of the ground staked lies above timber-line.

The ore deposits are fissure veins occurring both in the dyke and in the surrounding country rock. At the time the property was visited very little stripping work had been done, and most of the exposures consisted only of debris or float which was exposed on the surface. Consequently, very little idea could be obtained as to the value and extent of the deposits.

A group of six claims has been staked around the original discovery and bonded to the Yukon Gold Company which is doing the necessary development work to prove the value of the claims. The claims are the Roulette, Keno, Rico, Pinochle, Scottie, and Heather. There were five main showings of mineral on the claims; three on the Roulette and two on the Keno. The original discovery on the Roulette claim is a vein occurring in a small gulch opening into Ladue valley. At the time of the writer's visit it was largely covered by debris; but values in silver of 150 ounces per ton and upwards had been obtained from a series of samples taken by the holders. The main showing on the property lies at the shoulder of the hill, on the Roulette claim, very close to the border of the Keno. Stripping had uncovered a vein with a width of 6 feet striking approximately north 10 degrees east magnetic and dipping approximately 55 degrees to the east. The vein is stripped along the slope of the hill for about 20 feet, the upper 10 feet showing massive galena. The vein is then apparently cut off by a horse of country rock, but resumes immediately below. The width of the vein below the horse could not be accurately determined, but it is at least one foot and possibly more. The values obtained from this vein were as large as those of the original discovery or slightly higher. On the summit of the hill a third vein has been uncovered in the dyke rock. It has a width of one foot and like the other is massive galena. The dip and strike of the vein could not be accurately measured at the time of the writer's visit; but it is apparently a different vein from that previously described.

At other points on the surface of this group galena float occurs in such places as to make it certain that it comes from veins other than those described above. In many cases it is probable that the outcrops are not far away and that the material has been brought to the surface by frost action; in other cases solifluction or land creep has been active and it is impossible to say how far away the outcrops are. It will, therefore, require a systematic series of trenches to reveal all of the veins on the property.

Promising showings also occur on two claims owned by T. McKay and Axel Erickson. One of these claims is situated at the head of a small gulch tributary to Christal creek about a quarter of a mile to the east of the Heather claim. The vein was uncovered by a small open-cut running into the hillside, but owing to slumping no particulars concerning it could be obtained other than that the vein strikes in a general northerly direction. A good showing of vein material occurs on the dump and grab samples taken by the owners and assayed by the Territorial Assay office at Whitehorse run from 100 to 1,000 ounces in silver.

The second of these claims, the Nabob, adjoins the Keno on the northeast. The vein is exposed in a small cliff face, but owing to talus very little of it could be seen. It strikes in a general east-west direction and dips about 45 degrees to the south, and has a thickness of from 4 to 6 feet. Grab samples taken by the owners show values similar to those from their other claim. The vein-filling is composed of galena, iron minerals, and quartz.

The Silver Basin, owned by R. Rasmusen, lies about three-quarters of a mile to the northeast of the Keno. The vein matter exposed is not in place, but, in a small slide of debris from a rock chimney, occurs in such a manner that it could have come only a short distance. The vein material consists of iron carbonates and hydroxides, quartz, arsenopyrite, and galena.

On a number of other claims, finds of mineral have been reported and it seems probable that mineralization has taken place over a wide area, but owing to the fact that so little can be seen of any of the deposits, no conclusions can be drawn as to their origin or extent. It seems probable, however, that further prospecting will add greatly to the area around Keno hill where mineral has been discovered.

The prospects already discovered all contain a high grade ore which will stand mining and shipping even under adverse conditions, and many of them could be worked by hand methods of mining. The size of the deposits has yet to be determined, and this will be done in a number of cases during the present winter. If the ore-bodies are found to be of sufficient size, the construction of a good wagon road to the property would be necessary, as the present road, though good for winter haulage, would be absolutely impassable for heavy traffic during the summer. It is possible that hauling will take place to Gordon Landing rather than to Mayo as the route would be 10 miles shorter.

Mount Cameron.

Mount Cameron is situated about 45 miles in a direct line northeast of Mayo and the distance by the winter road now under construction to the property is approximately 65 miles. The Mount Cameron property is situated on the northern slope of mount Cameron at timber-line or approximately 3,500 feet above sea-level. It consists of three claims, Cameron No. 1, Cameron No. 2, and Cameron No. 3, owned by J. Alverson and J. Scougale.

The general geology of the district is similar to that of Keno hill, the country rock being composed of gneissoid quartzites, quartz mica schists, mica schists, and crystalline limestone, cut by dykes of diabase.

The workings consist of an adit 30 feet long and a crosscut 12 feet long. The mouth of the adit was blocked by caving at the time of the writer's visit, and consequently the underground workings could not be examined. The outcrop of the vein consists of a decomposed mass of iron and copper minerals; pyrite, limonite, siderite, malachite, azurite, and arsenopyrite; with galena, sphalerite, and calcite. The width of the mineralized cropping is about 50 feet. It is claimed that in the adit the vein has a banded appearance with alternating streaks of galena and sphalerite, the galena occurring in streaks from 2 inches to 6 inches wide.

It is not possible at the present time to make a fair estimate of the value of this property; the size of the cropping and the fact that streaks of pure galena carrying high values in silver occur, indicate that it may have considerable value, but much more development work is necessary in order to prove this. This work should include both sinking and drifting.

Rambler Hill.

A description of the Rambler Hill property has already been given[1] and nothing can be added to it at present; for work had just been commenced at the time of the writer's visit. It is the intention of the owners to sink the shaft to a depth of 200 feet during the coming winter.

Lookout Mountain.

The Lookout property has been taken over by the Yukon Silver-Lead Mining Company, an organization of local capitalists. The property consists of a group of five claims and several fractions, situated on a spur of Lookout mountain, on the western side of Bighorn creek, a tributary of McQuesten river. The outcrop is situated at an elevation of 3,500 feet or 174 feet above the level of the creek.

The development includes about 930 feet of underground work. The upper adit is 50 feet in length and is terminated by a winze 25 feet deep, following the inclina-

[1] Cockfield, W. E., Geol. Surv., Can., Sum. Rept., 1918, pp. 6B-7B.

tion of the vein. A second adit 39 feet below the upper and 90 feet to the north of it, is 59 feet long to the point where it taps the vein, and from this point a drift follows the vein until directly below the winze, and an upraise has been stoped to within 6 feet of the bottom of the winze. The third adit is 125 feet below the second, and 320 feet to the north. It is 135 feet long to the point where it taps the vein, and a drift following the vein has been run in a southerly direction for a distance of 305 feet. Forty feet from the point where the adit taps the vein, a winze was sunk on the vein to the fourth level, a distance of 55 feet measured along the slope, and 100 feet beyond an incline has been sunk to a depth of 90 feet. The fourth level was driven from the incline to the winze and extended north a few feet.

The vein follows a well-defined but irregular fracture in a gneissoid quartzite and quartz mica schist. It strikes from 120 degrees to 150 degrees magnetic and dips from 45 to 55 degrees to the northeast. The filling consists of manganite, pyrolusite, limonite, cerusite, anglesite, galena, and quartz. The hanging-wall is usually well-defined and marked by gouge, frequently showing an inch or more of impure graphite. The ore is of a disseminated character, the galena occurring in small streaks and masses. There are, however, several zones in which the streaks of galena occur in sufficient numbers to permit of sorting a shipping grade of ore. The uppermost of these was encountered in the prospecting shaft sunk from the upper adit. The size of this zone has not been determined, as it does not appear in the lower workings. In the second adit there are no well-defined zones, and although galena occurs plentifully along the foot-wall in a gangue of manganese minerals, it is as a rule more coarsely crystalline and carries less silver. In the third level there are two streaks of carbonate ore carrying very high but somewhat erratic values in silver. These streaks vary from 1 inch to 12 inches in thickness. Two zones occur between the third and fourth levels, one being in the winze and the other in the incline. Neither of these has been fully blocked out, but the ore-shoot occurring in the incline is probably the largest yet found. Five samples were cut across the portion of the ore-body that is exposed in the workings, four of the samples (Nos. 1 to 4) being taken in the incline, two above and two below the fourth level, the intervals between samples being 10 feet. Both sides of the incline were sampled and the material from the two cuts included in the one sample. No. 5 is a sample taken from the fourth level 10 feet from the incline. The samples were assayed[1] and the results are listed below.

No.	Gold, ozs. per ton	Value gold per ton	Silver, ozs. per ton	Value silver per ton at $1.20	Total value gold and silver per ton	Lead per cent
		$		$	$	
1...........	0·02	0 40	43·48	52 17	52 57	29·80
2...........	0·01	0 20	34·34	41 21	41 41	28·20
3...........	Trace	....	37·20	44 64	44 64	40·60
4...........	0·03	0 60	45·57	54 68	55 28	36·60
5...........	Trace	....	28·80	34 56	34 56	23·20

Development work at this mine is still proceeding. The incline is being sunk to water-level, and it is the intention of the owners to stope out and sort for shipment the ore occurring between the third and fourth levels.

Conclusions.

From the data that have already been collected in Mayo area, it is becoming increasingly more evident that the silver deposits occur in areas where the schists of the Nasina series have been cut by intrusions of basic and semi-basic rocks. This

[1] Assays by W. C. Sime, Territorial Assay Office, Whitehorse.

relation holds in too many cases to be of an entirely accidental character, and it would appear that there is a genetic relation between the two. This, however, can hardly be established until work of a detailed nature has been undertaken. Greenstones of two widely different ages are present, however, one being Pre-Cambrian and the other late Palæozoic or early Mesozoic. Both have apparently been epochs of mineralization, but until the areal geology of the district has been done very little can be said as to the effects of these intrusions. Some evidence also exists to show that the region has been subjected to earth movements subsequent to the formation of some of the ore deposits, and that the veins have undergone metamorphism.

The discovery of deposits of high grade ore on Keno hill is of great importance, as it shows beyond doubt that the Silver King vein is not an isolated occurrence. That other discoveries will be made from time to time seems highly probable. Nuggets of native silver are common in the placer gravels of the district. These have largely come from within the area itself, and represent portions of veins which have been eroded away. The field is consequently one that offers great inducements to the prospector, and it seems probable from what has already been discovered that areas where greenstones cut through the schists are the most likely places to prospect for silver deposits.

SALMON RIVER DISTRICT, PORTLAND CANAL MINING DIVISION, B.C.

By J. J. O'Neill.

CONTENTS.

INTRODUCTION.

The Salmon River district has attracted considerable attention within the last three years because of the discovery of deposits of very high grade silver ores. Before that discovery it had been considered that the future of the district depended on the possible exploitation of large, low grade deposits of complex ore, the first of which had been discovered in 1904.

The field work, on which the present report is based, occupied the summer of 1919, and was carried on concurrently with the making of a topographic map of the district by F. S. Falconer, of the Geological Survey, on a scale of one mile to an inch, and contour interval of 100 feet. This map, which is exceptionally accurate, is used as a base for the geology.

Reports of the progress of development work in this district have appeared in the reports of the British Columbia Bureau of Mines annually since 1909, and in one previous year, 1906, two years after the discovery of the Big Missouri. Mr. George A. Clothier, provincial resident engineer for the Portland Canal mining division, gave an excellent description of the various properties in the report for 1917.

In 1911 R. G. McConnell, of the Geological Survey, made a reconnaissance of the Salmon River district and a report and geological map were published in 1914 (Memoir 32).

The writer is indebted to most of the mining men in the district for information, and other courtesies, especially to Mr. A. Harris, of the Mineral Hill group; Mr. Sturtevant, of the Big Missouri, and Mr. Irving, of the Premier mine.

LOCATION: MEANS OF ACCESS.

The district is situated in the northwestern part of British Columbia, adjoining the Alaska boundary, 14 miles from tide-water at the head of Portland canal. Portland canal, one of the largest of the numerous fiords which indent the north Pacific coast, is about 90 miles in length, and cuts completely through the Coast Range batholith of granitic rocks to the sedimentary and volcanic rocks which border the batholith on the east. Thus, the district is situated near the eastern side of the Coast range, in the zone immediately bordering the granitic rocks, which is, throughout British Columbia, so commonly found to be mineralized.

The area of the district examined is about 60 square miles. It is bounded on the east by the divide between Bear and Salmon rivers; on the north by the divide between Salmon and Nass rivers, and on the west and south by the Alaska boundary.

Access to the district is by way of the valleys of Salmon river and its tributary, Cascade creek. The main Salmon river, which lies wholly in Alaska, empties into the canal about one-half mile from the Alaska boundary, at the town of Hyder, and 2 miles west along the coast from the Canadian town of Stewart.

At present goods are taken by launch from Stewart to Hyder, but a first-class level-grade road between the two towns is nearing completion. A good wagon road extends from Hyder, along the east bank of Salmon river for 11 miles, on a grade of about 25 feet to the mile, and is being extended about 8 miles farther across the boundary to the Joker Flats. The goods required by the various mining camps are now taken from Elevenmile by pack horses. The difference in elevation between Elevenmile and the Joker Flats is about 2,500 feet. A good wagon road from Elevenmile to the Premier mine was completed in 1919.

A preliminary survey for a railway has been made from Hyder to Elevenmile, and it is expected that the large producing properties will send their ore to this place by aerial tram.

DISCOVERY AND HISTORY.

In 1904 prospectors from the Bear River valley crossed the divide into the country at the head of Salmon river, and staked the Big Missouri claims, which have an enormous outcropping of mineralized rock. This discovery caused an influx of prospectors, and soon most of the district was staked. The district was considered, up to 1917, to be one of large deposits of low grade complex ores, and the development was with a view to ascertain if sufficient quantities of workable ores could be proved to warrant the large expenditure required to exploit them. During 1917 very high grade silver ores were found on a number of properties, and the district has rapidly come into prominence as a prospective high grade camp, as well as a possible low grade one on a large scale; all efforts at present are devoted to proving the high grade properties, and one exceptionally rich property has become a producer. Several others show a reasonable prospect of becoming such.

SUMMARY AND CONCLUSIONS.

Two distinct types of deposits occur in this district. The first type consists of deposits of low grade complex ore, which occur in great quantity in places, as for example on the Province claim of the Big Missouri group. These ores run from $6 to $10 per ton in all values in the following proportions; about three-fifths of the value in zinc; one-fifth in lead; and the other fifth in gold and silver; with a little copper. A considerable amount of experimental work will be necessary to develop a process to treat these ores economically, before such properties can become producers.

The second type of deposits in the district is of high grade silver ores, which in places carry high values in gold. The principal silver sulphide is argentite, and freibergite probably ranks next; a little pyrargyrite is also present. Pyrite, sphalerite,

galena, and chalcopyrite occur usually in lesser amounts. The sphalerite and galena are also somewhat argentiferous. Native silver is of first importance in the highest grade ores and is due to secondary enrichment.

It is clearly shown on the geological map of the district that all the high grade deposits found so far are located in granodiorite porphyry very close to the contact with the intruded tuffs of the Bear River series. The large deposits of low grade material occur near the upper margin of the granodiorite porphyry, in rock which is apparently an intimate mixture of granodiorite porphyry and metamorphosed tuff. It is not evident what were the factors determining the presence of high grade ores in the deposits. There is a possibility that rich silver ores may occur below the low grade deposits, in the pure porphyry, and much more detailed study of the deposits will be required to determine the relationship of the two classes of ores.

In prospecting for, and development of, high grade deposits it should be remembered that the very rich ores occur at the intersection of systems of fissures, at which places secondary enrichment has played an important part in producing the deposits.

GENERAL GEOLOGY.

The oldest rocks in the district are a series of tuffs and tuffaceous conglomerates of various colours, red, green, and grey shades predominating. This series occupies most of the district and is overlain in the northwest and northeast parts by the Nass series of grey shales and sandstones. The Nass series occurs in isolated patches in various other parts of the district. Both these series were intruded by the granodiorite of the Coast range, and by numerous dykes which range from quartz porphyry to augite porphyrite, and which followed the main granodiorite intrusion. These dykes are the youngest rocks in the district.

The main granodiorite intrusion was preceded by intrusions of granodiorite-porphyry, which worked their way into the overlying rocks and cooled before the main intrusion had reached its climax, and the porphyry is actually cut by the granodiorite, although it was part of the same magma and has suffered a general regional shearing in consequence. An excellent description of a similar sequence of intrusions is given by Dr. J. A. Bancroft[1] in his report on the "Geology of the coast and islands between the strait of Georgia and Queen Charlotte sound, B.C." In that district the history of the intrusion can be clearly read in the great cliffs which border the fiords.

The regional shearing roughly parallels the border of the main granodiorite batholith. Along the Missouri ridge it strikes about north and south astronomic, and dips about 60 degrees to the west; near the Premier mine it swings nearly due east and west. This shearing was accompanied by strong silicification and pyritization, but without the formation of any valuable minerals. Later fissuring occurred at an angle of 45 degrees to the regional shearing and this is represented by veins of quartz which strike northeast and northwest; high grade silver minerals have been found in such veins, and enriched deposits occur at the intersections of any of these three sets of fissuring. Very few instances occur in the district of dykes which are younger than the ore deposits. Apparently the dykes had no effect on the primary mineralization, but they may in some cases have affected the secondary enrichment. A belt of dykes about three-quarters of a mile broad cuts across Bear ridge in a northwest direction, on the east side of Long lake; this belt includes at least a dozen different dykes, in which quartz porphyry predominates, and on the west side of Long Lake valley they separate and cross the south end of mount Dillworth in a broad belt interbanded with the tuffs which they cut.

GLACIAL GEOLOGY.

The whole district under consideration has been glaciated, and there are glaciers at present covering most of the country surrounding it. The Salmon River glacier,

[1] Geo. Surv., Can., Mem. 23.

and the ice-caps of mount Dilworth and of Bear ridge cover about one-quarter of the district. The glaciers are apparently in retreat at the present time. The main glaciation has been along north-south lines, and is represented by deep, U-shaped valleys and rounded hills. Following the main glaciation the ice from Bear ridge extended in tongues into Long Lake valley and a moraine from one of these tongues dammed up the southern outlet of the valley so that Long lake now drains into the west fork of Cascade creek, whereas it formerly drained into the east fork. From Long lake to Silver lake along Cascade creek there is a great series of falls which are post-Glacial, and the gorge is about 50 feet at one place.

ECONOMIC GEOLOGY.

Since most of the summer was spent in checking up and correcting the regional geology of the district as it appeared on the old map, a relatively small part of the time was available for the study of the economic geology. Only a general statement can be made here of the occurrence and characteristics of the deposits. Good general descriptions of the various properties are given in the reports of the British Columbia Bureau of Mines, and consequently only a few properties will be mentioned here by way of illustration. Since most attention is being paid to the deposits of high grade ore in the district, the low grade deposits were not studied in any detail.

Low Grade Ores.

Large deposits of ore which is a complex mixture of zinc blende, galena, chalcopyrite, and pyrite, occur along the top and western side of Big Missouri ridge, about the centre of the district. The deposits on the Big Missouri group have been under bond to several companies and have been opened up enough to show that they are of enormous extent. The average of a great number of samples shows that this ore runs about $7 to $10 a ton, but most of the values are in zinc, and it will be necessary to develop milling and metallurgical processes to treat this material before it can be utilized.

High Grade Deposits.

The primary high grade silver ores are found in quartz veins or silicified shear zones about the borders of the granodiorite porphyry intrusive. These veins for the most part strike northwest, although a few strike northeast, and they cut the regional shearing at 45 degrees. Properties containing high grade ores, so located, include the Big Missouri, the Mineral Hill, Bush Mines, Ltd., and the Premier. There are many other properties, but the occurrence of high grade ore in them has not been demonstrated.

The sulphide ores occur in varying amounts on the different properties and are known as the black ores. They are not nearly so prominent, or so spectacular as the native silver, and are sometimes overlooked. Samples of the black ore from the Premier mine and of another ore in which native silver appears very abundantly, were examined by H. V. Ellsworth of the Mineralogical Division of the Department of Mines, who reports as follows:

"*Specimen marked "Premier"*. Pyrite, sphalerite, probably galena, and pyrargyrite are disseminated in a gangue of mixed quartz and calcite. The pyrargyrite is abundant.

"*Specimen marked "Premier"*. Pyrite, sphalerite, probably galena, and pyrargy-a little pyrargyrite with pyrite, zinc blende, and probably galena in a gangue of quartz. I saw no calcite in this specimen.

"Qualitative tests on both samples showed the presence of lead, indicating galena. The soft black mineral gave much copper and antimony with silver, indicating freibergite. Its physical properties do not agree with polybasite, which would give the same qualitative tests. No bismuth was detected."

, On the Spider group, north of Long lake, very high grade ore occurs in small veins of quartz in a small stock of augite porphyrite; this ore is said to have assayed 1920 ounces of silver, and $26 gold to the ton. A specimen of this ore was examined by H. V. Ellsworth, who reports as follows:

"*Sample marked "Spider"*. The specimen shows large amounts of various sulphide minerals in a gangue of quartz.

The chief metallic minerals present are sphalerite, galena, and argentite, with lesser amounts of freibergite, native silver, chalcopyrite, and pyrite. Argentite, the chief silver mineral, occurs in important amounts. Freibergite probably ranks next in importance, and native silver, in mossy or hairlike forms, occurs only in small quantity associated with the argentite. The sphalerite and galena are also argentiferous, though without mineralographic examination one cannot be sure that the silver content is not due to an admixture of definite silver minerals. The quartz gangue shows numerous vugs lined with inwardly projecting quartz crystals and wholly or partly filled with sulphides, usually argentite. There are some films or stains of oxidized material containing iron, copper, lead, or zinc."

It appears that the values in gold are much higher in deposits near the contact of the main granodiorite intrusive.

Silicification of the wall-rock of the veins or fissures is very pronounced and intersections of veins are expressed on the surface by knolls which stand up above the surrounding rocks.

The general regional shearing is not uniformly distributed, but is concentrated in zones. Where the northwest or northeast ore-bearing veins cross such zones, or where they cross one another, there is an enrichment of the deposits in the form of native silver. In some places a series of the later fissures cross a main zone at relatively close intervals, and the enrichment has spread along the zone between them; such a case occurs on the Mineral Hill property, and the rich ore terminates along the strike a short distance beyond the intersection of the outer fissures of the series.

Where the main zone of fissuring is wide, as on the Premier, and the cross-fissures are strong, considerable amounts of very rich ore have developed across most of the width of the main zone along the cross-fissures, and has spread along the main zone between cross-fissures.

A mistake has been made on some properties by assuming that the whole main zone is mineralized along the strike with high grade ore; this is not the case. It must be borne in mind that the primary sulphides are confined usually to the cross-fissures, which are relatively small, that the native silver occurs usually about the intersections, and that the main zones in the gaps between cross-fissures contain ore of a relatively low grade. On the Premier mine these gaps are said to carry about $7 ore, and probably can be mined with the high grade (which runs several hundred dollars in silver and gold), but on properties where the cross-fissures are smaller, or spaced farther apart, the gaps between cross-fissures contain rock running $1 to $2 to the ton, and cannot be economically mined alone. It follows that the latter properties must mine narrow veins of rich ore, or develop into larger low grade properties in which the rich ore is used to bring up the general grade.

It is important to note that the shear zones in the porphyry apparently break up or flatten out in passing to the overlying tuffs, and the deposits lose their continuity and usually their high values; this is excellently demonstrated on the Big Missouri, Mineral Hill, Bush Mines, Ltd., and on the Premier, all of which include both porphyry and tuffs.

Very careful testing should be made on each property to determine the extent and general average of the high grade ore before any heavy expense is undertaken in the purchase of mining machinery, or in the way of transportation improvements.

Many properties in the district do not come under either of the above described groups of deposits. Certain deposits of lead-zinc ores in quartz veins carry considerable silver, but on others the silver values are almost negligible.

A number of problems still remain to be worked out, in the general as well as in the economic geology of the district, before development work on the prospects can be intelligently carried out or places made for actual mining operations that will not entail a great amount of useless expenditure of both time and money. Among these problems are the relations of the ore-bodies to certain formations and the structures in these formations, the causes and extent of enrichments, and the relations of the low grade ores to the high grade ores.

BARKLEY SOUND, VANCOUVER ISLAND, B.C.

By Victor Dolmage.

CONTENTS.

INTRODUCTION.

In continuation of a general plan, inaugurated in 1918, to make a geological map and mineral survey of the west coast of Vancouver island, six weeks of the season of 1919 were spent in mapping the shores and islands of Barkley sound. The work was facilitated by the able and enthusiastic assistance given by R. C. Emmons.

DESCRIPTION OF THE DISTRICT.

Barkley sound is the most southerly of the six large sounds which indent the west coast of Vancouver island and is situated about 80 miles northwest of the southern end of the island, just south of the 49th parallel of latitude and west of the 125th meridian. Like all of these sounds it consists of a wide gulf choked with numerous islands and long, narrow inlets extending far into the interior of the island, some of which terminate within a few miles of the east coast.

The gulf part of Barkley sound is about 15 miles wide and extends inland about 14 miles in a direction north 40 degrees east. It is divided into three channels, the Eastern, Middle, and Western, by two groups of islands lying parallel with the eastern and western shores of the sound. The eastern set, called Deer islands, consists of six long narrow islands lying close together and a number of small islands scattered along the western side of the group. The western set, called the Broken group, forms a broad band of closely spaced islands extending along the middle part of the sound and contains not less than a hundred islands of sufficient size to map on the charts, besides a great many smaller islets and rocks indicated by dots or crosses. In the Western channel there are twenty or more good sized islands, not closely spaced but forming a roughly defined chain parallel with and close to the western shore. The total number of islands in the sound is less than three hundred, all of which are rocky and, excepting Deer islands, rise only a few tens of feet above sea-level. Many rocks lying just below the surface or appearing only at low tide, add to the difficulties encountered in navigating the channels.

Three inlets extend inland from the sound, each being a continuation of one of the three channels. They are all long and narrow and are bounded on each side by high, almost perpendicular, cliffs which rise behind to lofty mountains. Alberni canal, a continuation of the Eastern channel, has a length of about 25 miles and an average width of about three-quarters of a mile. At its head is situated Port Alberni, the only town on the west coast reached by a railway. From the sides of the canal rise high

mountain ranges which are cut through by several deeply scoured, transverse valleys. Those entering from the northwest are the most pronounced and each is occupied by a large freshwater lake situated only a few miles back from the canal. One of the largest of these valleys, entering from the northwest near the mouth of the canal, is occupied for the first 3 miles by an arm of the canal, called Uchucklesit harbour, and above for half a mile by two rivers draining lakes of which the larger, known as Henderson lake, is 12 miles long.

Effingham inlet, a continuation of Middle channel, extends in a northerly direction with a graceful curve westward for a distance of 10 miles, ending in a cluster of snow-capped mountains.

Pipestem inlet, an extremely narrow, straight gorge running in a northeasterly direction, extends from Western channel for 7 miles and ends within half a mile of Effingham inlet.

At the western side of the sound a narrow, shallow inlet called Ucluelet arm extends for 5 miles parallel to the trend of Vancouver island and is separated from the Pacific by a low, rocky peninsula less than half a mile in width.

From the above description of Barkley sound it will be seen that, owing to the length and irregularity of the shore-line and the great number of islands, it offers an excellent opportunity for shore geology. This opportunity is still further increased by the fact that, excepting for short distances near the mouths of the rivers, the shores show continuous outcrops of the bedrocks.

Because of this, and also because the only available maps of the district are the marine charts issued by the British Admiralty, work was largely confined to the shore-line. The charts used were on a scale of about 1½ inches to the mile, which enabled the mapping to be done in considerable detail. All the ore deposits within a mile or two of the shore were visited and the shore geology extended inland to include them. In five weeks nearly 300 miles of the shore-line of the sound and of the islands and inlets was mapped.

GEOLOGY.

The following remarks concerning the geology of Barkley sound are necessarily of a very preliminary nature owing to the fact that there has been no opportunity of examining microscopically any of the rocks encountered in the field.

Previous workers in the district are Haycock and Webster[1] and Clapp.[2]

The pioneer work of Richardson on the Cretaceous of Vancouver island and of Dawson on the geology of the whole island laid the broad foundations on which later geological investigations were based. The researches of Clapp, some of which were in great detail, cover the greater part of Vancouver island south of Barkley sound and these researches, in conjunction with those of Richardson and Dawson, established with some degree of certainty the age and classification of all the rocks known to occur on Vancouver island. The present investigation is to a large extent, particularly in its present preliminary stage, a continuation of the above-mentioned researches.

[1] Haycock, E., and Webster, A., Geol. Surv., Can., Sum. Rept., 1902, p. 54.
[2] Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912.

The following table of formations, based on Clapp's work, but containing only the rocks found in Barkley sound, applies with a few minor differences to this district.

Table of Formations.

Age	Formation		Character
Recent	Recent deposits		Stream gravels
Unconformity			
Pleistocene ?	Wreck Bay formation		Stratified sands, gravels, and clays
Unconformity			
Upper Cretaceous	Nanaimo formation		Sandstone and shale with small amount of coal
Unconformity			
Upper Jurassic ?	Coast Range batholith	Saanich granodiorite	Granodiorite and quartz-diorite
		Intrusive contact	
		Beale diorite	Diorite
Intrusive contact			
Lower Jurassic or Upper Triassic	Vancouver group	Vancouver volcanics with Nitinat and Sutton formations	Andesites, tuffs, etc., with interbedded limestone

Vancouver Group.

The Nitinat formation described by Clapp[1] consists of a series of highly altered limestones found usually included in the rocks of the Coast Range batholith and thought to be an early member of the Vancouver group. But the evidence on this point was very meagre and left serious doubts as to whether it might not belong to the Leech River or Malahat formations, which are much older than the Vancouver group.

In Barkley sound many small areas of these rocks were found, usually enclosed by the Beale diorite or Saanich granodiorite, but in a few places, such as on Copper island, they were found interbedded with the andesites of the Vancouver group and the relations there shown substantiate the view that they belong to an early period of this group. The largest exposures of the Nitinat formation were found at Sechart on Quoin, Hawkins, Storm, Howell, and Village islands. None of the exposures are more than a few thousand yards in diameter and they consist of very highly altered limestone and volcanic rocks composed largely of hornblende and tremolite with a few

[1] Clapp, C. H., Geol. Surv., Can., Mem. 13, p. 44.

sulphides, and occasionally magnetite in considerable quantities. The mercury deposit near Sechart occurs in one of these remnants of altered limestone.

The members of the Vancouver volcanics occur in numerous places along Alberni canal, Effingham, Pipestem, and Ucluelet inlets, and on Copper island. In a general way, the exposures of these rocks are larger and more numerous in the eastern part of the district and gradually give way, in the western part, to large intrusive masses of granodiorite and diorite.

The volcanic rocks consist almost entirely of andesite and andesite tuffs, the former greatly predominating. They are steeply folded along axes striking roughly parallel with the main axis of the island, i.e. about north 60 degrees west.

Interbedded with the andesites are many small beds and lenses of limestone, which Clapp has named the Sutton formation. These limestones are exceedingly pure and usually found crystallized to marble. Where the diorite and granodiorite intrusive have cut them, they are metamorphosed to a high degree and consist of garnet, tremolite, epidote, and, in some localities, commercial quantities of copper ores and magnetite.

The rocks of the Vancouver group, including the Nitinat and Sutton limestones, the oldest in the district, are intruded by the rocks of the Coast Range batholith and are overlain unconformably by Upper Cretaceous sediments.

Coast Range Batholith.

The two batholithic rocks named by Clapp, the Beale diorite and the Saanich granodiorite, are the most widely distributed rocks exposed in Barkley sound and were so easily distinguished in the field as to make it possible to map them separately.

The Saanich granodiorite, in a general way, lies to the east of the Beale diorite and occurs in two large, irregular bodies, one on Alberni canal and the other extending in a northerly direction from the east shore of Barkley sound, in the vicinity of Grappler creek, across Robbers and Copper islands, striking the shore of Vancouver island again at Vernon bay just east of Effingham inlet. West of this body the country is composed of Beale diorite with small remnants of the Vancouver group scattered through it. The area underlain by these batholithic rocks is bounded on the east, north, and west by the rocks of the Vancouver group, the eastern boundary lying near the head of Alberni canal, the northern boundary just south of Pipestem inlet, and the western boundary east of Ucluelet arm. The Saanich granodiorite is a light grey, medium coarse rock consisting of plagioclase, quartz, and hornblende with probably some orthoclase and small amounts of biotite and magnetite. The quartz and feldspar greatly exceed in amount the dark coloured constituents, giving the rock its noticeably light colour. Near its contacts it is usually much finer grained and in places porphyritic.

The Beale diorite is characterized by a darker grey colour owing to its greater proportion of hornblende, biotite, and magnetite, its nearly total lack of quartz, and the darker colour of its plagioclases. In many places near its contact are found a large number of darker coloured, finer grained, segregations or inclusions of similar composition. In places these become so numerous as to form over 50 per cent of the total volume of the rock.

Both the Beale diorite and Saanich granodiorite intrude the rocks of the Vancouver group, and the Saanich granodiorite intrudes the Beale diorite. Clapp considers that both these rocks belong to the Coast Range batholith and that the Beale diorite is a marginal phase of the batholith and, therefore, slightly older than the Saanich granodiorite. The observations made last season by the writer seem to substantiate this view. The age of the rocks is believed to be upper Jurassic and possibly Lower Cretaceous.

Nanaimo Formation. The Cretaceous sedimentaries of the Nanaimo formation do not outcrop on the shores of Barkley sound excepting at the head of Alberni canal on the southwest side. There, these rocks, consisting of conglomerate, sand-

stone, and shale, outcrop along the shore for about one mile and are found to overlie the Saanich granodiorite. The shale which is exposed near the wharf at Port Alberni contains a small seam of coal of no commercial value.

Wreck Bay Formation.

The only formations younger than the Upper Cretaceous are the recent river gravels deposited about the mouths of the streams; glacial drift, which is seldom found near the shore, but is widely distributed inland, and a formation of considerable extent composed of stratified sands, fine gravels, and clays, lying to the west of Barkley sound. The latter formation, which will be referred to as the Wreck Bay formation, outcrops along virtually the whole of the western shore of the sound from Toquart harbour to Ucluelet and extends back from the shore about a mile to the base of a lofty range of mountains. It occurs along the northeastern shore of Ucluelet and along the main shore of the island as far as Clayoquot sound and is exposed inland as far as Kennedy lake, a distance of 10 miles. The base of the formation is exposed at numerous localities along the shore where it is seen to lie on the rocks of the Vancouver group and of the Coast Range batholith. The formation forms a level plain with an elevation of from 50 to 60 feet above the sea and is bounded along the shore-line by a perpendicular wave-cut cliff at the base of which are long, sandy beaches sloping gently seawards. Some of these beaches contain black sand carrying small quantities of gold.

It is probable that this formation was deposited during an interglacial period and it may be correlated with similar deposits described by Clapp[1] which occur in the southern part of Vancouver island.

ECONOMIC GEOLOGY.

No minerals except small quantities of gold which were recovered from the beach placers of Wreck bay have been produced from this district since 1902. Previous to that date small shipments of copper ore had been made from the Monitor mine and Hayes mine, both of which are situated on Alberni canal. The latter mine was closed in 1902 and abandoned in 1910, but development work has been done on the Monitor as recently as 1918. It is possible that this mine will again become a producer.

A great many small copper deposits which have not yet been developed beyond the prospect stage, occur throughout the district. Several deposits of magnetite occur in the district, some of which may become valuable if a demand for the ore is created by the establishment of an iron and steel industry on the British Columbia coast. A small deposit of mercury occurs on Sechart peninsula, but it is of doubtful value.

Placer Deposits. The placer deposits are not actually in the territory included in this report but are situated on the outside shore of the island just northwest of Ucluelet in Wreck bay. They were briefly described by the writer in the Summary Report for 1918. The locality was again visited during this season, but the deposits were not being worked. Samples were taken and the results of the assays are included in the following table:

Sample No.	Gold		Metals of platinum group		Total value
	Oz. per ton	Value	Oz. per ton	Value	
		$ cts.		$ cts.	$ cts.
Black sand... No. 1......	13·02	260 40	0·05	5 00	265 40
" .. No. 2	Trace	....	....	....	....
" .. No. 3......	3·6	72 00	0·03	3 00	75 00

[1] Clapp, C. H., Geol. Surv., Can., Mem. 96, p. 353.

Sample No. 1. This sample consisted of the concentrates from three pans of sand taken from the beach at the base of a wave-cut cliff in the Wreck Bay formation.

Sample No. 2. The sample consisted of the concentrates panned from about 2 cubic feet of sand and gravel taken from a well dug in the Wreck Bay formation at a point about 2 miles inland from Wreck bay. The sample was taken from the upper surface of a small bed of fine clay which occurred at a depth of 4½ feet below the surface.

Sample No. 3. The sample is average black sand, not panned, taken from the beach at the base of the cliff.

The assays were made by R. D. McLellan of the Dominion of Canada Assay Office, Vancouver, B.C.

The amount of available sand of workable tenor is limited to a few hundred tons, but is replenished from year to year by the action of the waves on the shore. The gold content of the gravels of the Wreck Bay formation, which have not been affected by wave action, is too low to be worked even on a large scale. This is shown by sample No. 2 which was taken from the upper surface of one of the thin beds of fine clay which lie between the sand and gravel beds and which are usually found to be the richest horizons in the formation.

Copper Deposits.

The copper deposits are all of the contact-metamorphic type formed at the contacts of the batholithic intrusives with the limestones of the Vancouver group. They consist of disseminations of chalcopyrite, pyrite, magnetite, and rarely bornite in altered limestone consisting of garnet, hornblende, actinolite, epidote, tremolite, and calcite. These disseminations are exceedingly irregular in size, shape, and tenor, a feature which makes them both difficult and expensive to work.

The Monitor, which is now the most important mine of the district, has already been briefly described[1]; no work has been done on the property since the report was written, but the geology of the neighbourhood has been studied and the following information may be added to that contained in the above-mentioned report.

The most important facts brought out by completing the examination of the geology of the district surrounding this deposit are: (1) that the limestone mass containing the deposit is of very limited extent on the surface, but of considerably greater extent underground; (2) that it is bounded on the east by a large body of granodiorite outcropping for 2 miles on both sides of Alberni canal; (3) that ore was formed by solutions from the granodiorite lying to the east, as well as by solutions from the dyke of granodiorite porphyry which was mentioned in the above report as bounding the deposit on the west and which is now regarded as probably a contact phase of the granodiorite; and (4) that the adit on the so-called "new workings" is located only a few hundred feet west of the contact between the limestone and the granodiorite, and the faces of practically all the crosscuts, as well as the adit itself, are in limestone.

From these facts it may be concluded with a high degree of certainty that if the crosscuts, which now end in limestone, are continued to the east they will, within a few hundred feet, reach the granodiorite contact, and that in the vicinity of that contact the limestone will, in some places at least, be metamorphosed into garnet, epidote, etc., with which in some cases will be associated copper ores, probably in commercial quantities.

The discovery, therefore, of this granodiorite contact lying a short distance to the east of the adit should have an important bearing on the future development of the property.

[1] Geol. Surv., Can., Sum. Rept., 1918.

The other deposits of copper are all situated on the limestone-granodiorite or diorite contacts and have all the characteristics of contact metamorphic deposits. They are not developed sufficiently to merit separate descriptions, but it may be said that some of them may eventually prove to be of commercial value.

Magnetite Deposits.

The magnetite deposits have been untouched and in some cases unvisited for many years, during which time the trails leading to them have been obliterated by vegetation and many of the workings have been obscured by caving as well as by vegetation. It is, therefore, now impossible to make a complete examination. They have, however, been fully described from the commercial aspect by Einar Lindemann[1] and W. M. Brewer[2] and from a geological standpoint by C. H. Clapp.[3]

They are, like the copper deposits of the district, also of the contact metamorphic type and occur in the metamorphosed limestones of the Vancouver group at the contacts of the Coast Range batholithic intrusions. In this district the magnetite deposits occur at the contacts between the more highly metamorphosed limestones of the Nitinat formation and the Beale diorite, whereas the copper deposits are confined to the less altered limestones of the Sutton formation at their contacts with granodiorite intrusions. The magnetite is associated with pyrrhotite, pyrite, chalcopyrite, garnet, tremolite, actinolite, epidote, quartz, and calcite. The most abundant gangue mineral of the magnetite deposits is tremolite, whereas in the copper deposits this mineral is rare, and its place is taken by garnet and actinolite.

The deposits contain considerable quantities of magnetite which is usually found to be very pure, containing very small amounts of phosphorus and a little sulphur. They are all located within easy distance of the shore and it is highly probable that some of them will become valuable if an iron and steel industry is established on the British Columbia coast. However, they all have the great defect, characteristic of contact metamorphic deposits in general, and of those of Vancouver island in particular, of excessive discontinuity and irregularity in shape and size.

For a detailed description of the individual deposits the reader is referred to the before-mentioned authors.

Mercury Deposits.

The mercury deposit is of interest because it is one of the only two occurrences of the metal known in British Columbia, west of the Kamloops deposits. It is situated on a small creek which enters Sechart channel a quarter of a mile east of the Sechart whaling station. It is half a mile from the beach and, therefore, within easy reach of transportation.

Geologically it is situated in a small remnant of the Nitinat formation which is included in the Beale diorite at a point very near its contact with the Saanich granodiorite. This inclusion extends from the shore, where it has a width of less than a quarter of a mile, inland for about 2 miles in a northeasterly direction, its width increasing to a mile or more. The mercury occurs on the southeast contact of the inclusion within half a mile from the shore, and on the northeast contact of the inclusion are several deposits of magnetite of commercial size. Most of the mercury is contained in the inclusion itself, but small quantities occur also in altered diorite near the contact. The inclusion consists of limestone interbedded with andesite, tuff, and breccias, all of which have undergone intense alteration. The altered andesites consist largely of quartz in the form of very minute crystals, but occasionally as groups of larger crystals lining cavities. Besides the quartz are chlorite in varying amounts,

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[1] Lindemann, Einar, "Iron ore deposits of Vancouver and Texada islands," Dept. of Mines, Can., Mines Branch, Pub. No. 47.

[2] Brewer, W. M., Ann. Rept. of the Minister of Mines, B.C., 1916, p. K 283.

[3] Clapp, C. H., "Southern Vancouver island," Geol. Surv., Can., Mem. 13.

pyrite, hematite, and small residual grains of aplite. Calcite stringers are plentiful and much later in deposition than the above-mentioned minerals. Later than the calcite were deposited cinnabar, native mercury, and limonite. The cinnabar in places is very plentifully disseminated in the altered andesites.

The limestones are altered also to a mixture of quartz and amorphous silica which resembles that in the andesites but lacks the groups of larger crystals. No garnets were found. Tremolite, the most abundant mineral in the limestone of other parts of the inclusion, is not associated with the mercury ore. Cinnabar is not as plentiful in the limestone as in the altered andesite.

The breccias consist of fragments of quartz and limestone in a matrix of altered volcanic rock similar to the andesite but usually lighter in colour. In these breccias the cinnabar shows a marked preference for the quartz and limestone fragments, particularly the former, and pyrite, and in rare instances chalcopyrite, occur in the matrix.

The diorites are altered to a rock of a pale green colour and consist of calcite, chlorite, kaolin, actinolite, and quartz. The original feldspars can be distinguished only as pseudomorphs of the above-mentioned minerals. Calcite veins in the diorite are abundant and with these are associated cinnabar, serpentine, and pyrite.

Dykes of granodiorite which show no signs of either metasomatic or dynamic action occur cutting both the diorite and the inclusion, but none were observed nearer than a quarter of a mile from the mercury deposit.

Elsewhere along the contacts of the inclusion the diorites are found to be highly altered, but instead of the above-mentioned minerals, tremolite, garnet, actinolite, hornblende, epidote, pyrite, chalcopyrite, and large bodies of magnetite are found. The absence of these minerals from the mercury deposit and the presence of quartz, amorphous silica, and calcite, suggest that the earlier minerals were replaced by the quartz and calcite at a later period. The pyrite of the mercury deposit was formed probably by the same solutions that deposited the cinnabar, but the chalcopyrite, which was found in very small amounts, was seen under the microscope to be of an earlier period of deposition than the pyrite and may, therefore, be a residual of the minerals deposited by the solutions emanating from the Beale diorite at the same time that the magnetite deposits were formed.

It is difficult to account for the origin of this mercury because of its geological associations. The rocks in which it occurs are of Triassic and Jurassic age and the Saanich granodiorite, which outcrops in the near vicinity of the deposit and is the youngest rock known to occur in this region, is of upper Jurassic age. The cinnabar shows, by its intimate association with the limonite, that it was deposited at a very recent date and is related to the present erosion surface. In view of these facts it is impossible to imagine that the mercury had its origin in the magma of any of the rocks with which it is associated. The present surface must have been buried under several thousand feet of material that has since been removed by erosion, at the time when mineralizing solutions were emanating from the interior portions of the Saanich granodiorite and at such a depth the conditions of temperature and pressure would be higher than those under which cinnabar is known to be deposited.

The presence of magnetite deposits associated with garnet, tremolite, etc., which were deposited during the period following the intrusion of the Beale diorite, is conclusive proof that the cinnabar deposits are in no way related to that period of mineralization.

Two facts make it appear probable that indications of igneous activity of late Tertiary times may be found in this region when it has been more extensively explored by geologists, and that the mercury of this deposit had its origin in the magmas of that period. The first is that a large belt of basalts and gabbros of late Tertiary age occurs in the southern portion of Vancouver island at a distance of about 50 miles from this deposit, and the second is that a hot spring which issues from a crevice in

the rocks of the Saanich granodiorite formation exists at Sharp point[1] about 50 miles to the northwest. Unless igneous activity has taken place more recently than late Jurassic the existence of a spring such as this is difficult to explain.

It is possible that a spring similar to that at Sharp Point may have at one time existed near this deposit of mercury and may have deposited the cinnabar. It is known that cinnabar is at present being precipitated by the waters of many hot springs in California and Nevada, such, for example, as those at Sulphur Bank, California, Steamboat Springs, Nevada, and Rabbit Hole Sulphur deposit, Humboldt county, Nevada. It is found that mercury is precipitated by springs whose waters carry sodium chloride, sodium carbonate, and sodium borate, and the Sharp Point spring is of the sodium chloride type.

It is difficult to judge the size of the deposit from the exceedingly poor exposures that exist. For a distance of about 200 yards along the creek small patches of very lean ore of no commercial value are promiscuously scattered in the country rock. Near the south end of the showings is a large dump containing several thousand tons of ore taken from a shaft that could not be examined on account of the water which filled it, but the ore on the dump consisted of impregnations of cinnabar and native mercury in andesite, limestone, and breccia. Some of the specimens of impregnated andesite were quite rich, but the limestone and breccia formed only lean ore. A sample of the dump taken across its height assayed 0·38 per cent mercury.

It is the writer's opinion that with thorough prospecting a commercial deposit of mercury might be discovered in this vicinity.

SUNLOCH COPPER DISTRICT, B.C.

By Victor Dolmage.

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Illustrations.

INTRODUCTION.

The Sunloch copper deposit, situated on Jordan river, Vancouver island, was discovered a few years ago by George E. Winkler of Victoria, who, after doing the necessary development work, had the claims crown-granted and in 1917 bonded them to R. H. Stewart and associates of Vancouver. A company was organized called the Sunloch Mines, Limited, which is now developing important ore-bodies on the property.

The mine, though still in an early stage of development, promises to become eventually an important producer of copper. Its development is of peculiar interest to the people of British Columbia since it is one of the very few mining ventures which are being successfully developed by a local company of comparatively small investors.

[1] Clapp, C. H., Geol. Surv., Can., Sum. Rept., 1913, p. 80.

The situation of the property with reference to transportation, power, water supply, and easy accessibility, is almost ideal. The workings are located on the steep banks of Jordan river, 2 miles above its entrance into the strait of Juan de Fuca and only 40 miles west of Victoria. It is connected with the beach by a narrow-gauge tram-line running down to the mouth of the canyon, and a standard gauge logging railway which terminates at a wharf near the mouth of the river. The hydro-electric generating plant of the Vancouver Island Power Company, capable of supplying ample power for all purposes, is located within 2 miles of the tunnels. A good motor road, over which is maintained a tri-weekly stage service, runs from Victoria to the settlement near the mouth of Jordan river. The river furnishes a convenient and ample water supply for milling purposes.

GEOLOGY.

The geology of the district surrounding the Sunloch mineral deposit is similar to that of the western half of the Sooke sheet, which lies not more than 2 miles east of the workings on the Sunloch claims. The geology of the Sooke sheet has been worked out in detail and fully described by C. H. Clapp,[1] and C. H. Clapp and H. C. Cooke[2].

According to these authors, three formations comprise the geology of this part of Vancouver island, the Metchosin volcanics of lower Tertiary, the Sooke gabbros of middle Tertiary, and the Sooke formation of upper Tertiary age. The Sunloch and adjacent mineral deposits are at or near the contacts of a mass of Sooke gabbro which intrudes the Metchosin volcanics.

The Sooke formation which consists of partly consolidated, finely bedded sediments unconformably overlying the other two formations, does not outcrop on the area described in this report. It does, however, outcrop a few hundred yards to the south of Sinn Fein creek which crosses the Black Hornet claim and enters Jordan river just below the Vulcan claims.

The distribution of the other two formations in the vicinity of the claims is shown on Figure 1. The gabbro mass extends eastward, probably beyond the boundary of the Sooke sheet, and it is highly probable that it may be connected, at no great distance below the surface, with one of the gabbro masses which outcrop a short distance east of the Sooke sheet boundary. This is an important consideration with reference to the probable size of the Sunloch ore-bodies, because this small mass of gabbro, which is concluded to be the source of the ore, might be expected to produce a much larger quantity of ore if it were an off-shoot of some nearby larger mass of gabbro and not a small independent and isolated mass.

Metchosin Formation.

Distribution and Extent. Of the three formations the Metchosin is much the largest, occupying a belt from 5 to 7 miles wide, which extends along the southwest coast of Vancouver island from Albert head to Lost river, a distance of 35 miles. Except for two small remnants of the Sooke sediments, and five or six small intrusions of Sooke gabbro, the Metchosin volcanics are the only rocks outcropping in this area.

Lithology. This volcanic series includes all the usual types, such as amygdaloids, agglomerates, flow breccias, and tuffs, but all are distinctly basic in composition. The normal basalt consists of labradorite ranging from $Ab_{30}\ An_{70}$ to $Ab_{40}\ An_{60}$, and augite with accessory magnetite and apatite. It varies in texture from microcryptocrystalline to medium coarse-grained. It commonly has the diabasic structure well

[1] Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912.

[2] Clapp, C. H., and Cooke, H. C., Geol. Surv., Can., Mem. 96, 1917. Cooke, H. C., Geol Surv., Can., Mus. Bull. 30, 1919.

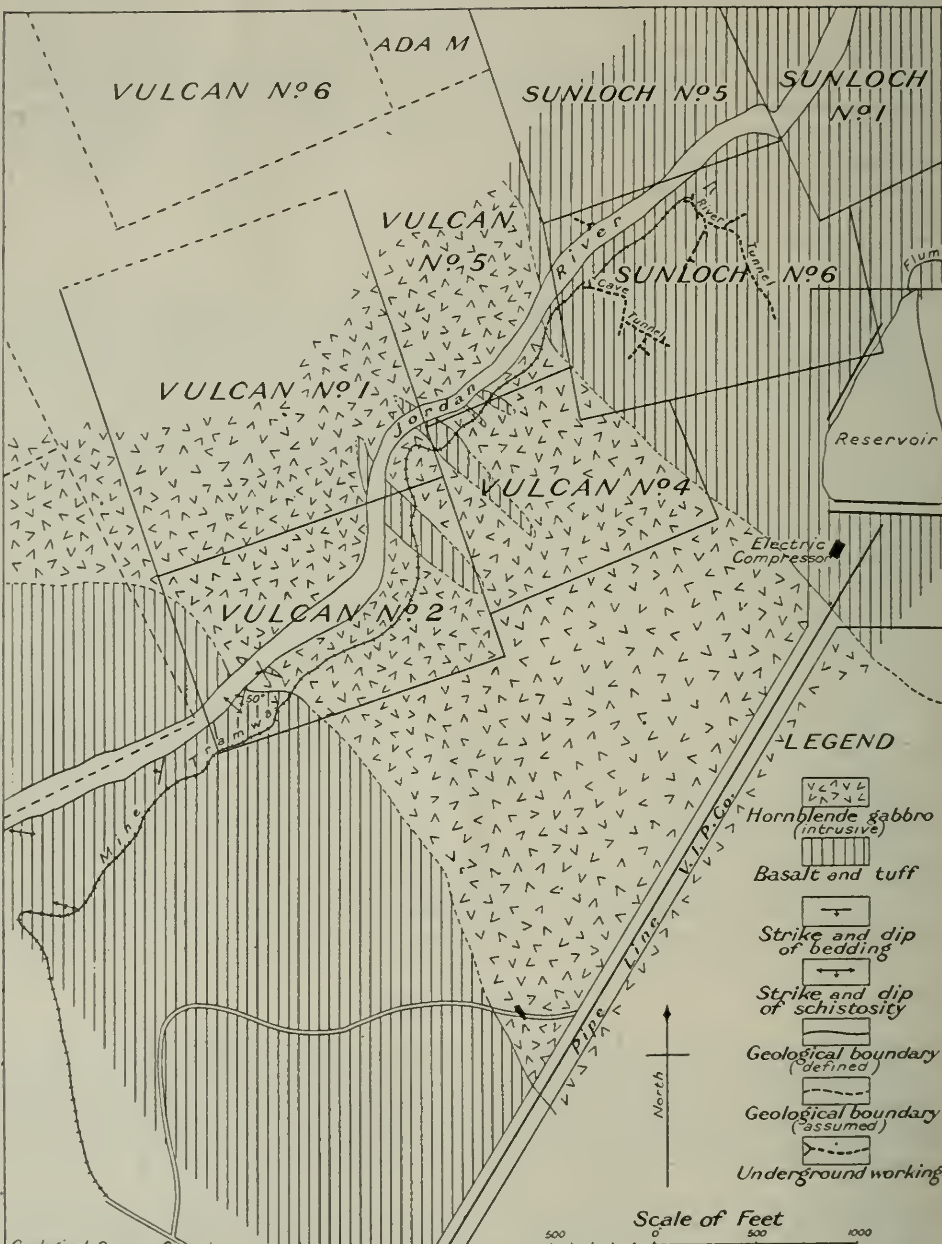

Figure 1. Sunloch copper deposits, Jordan river, Vancouver island, British Columbia.

developed, and in some places it is distinctly porphyritic. The coarse-grained varieties strongly resemble the gabbro intrusions. The flows are found in places to be cut by diabase dykes which are clearly related to the volcanic types, and are identical with many of the basalts.

Metamorphism. The alteration of these basic lavas and tuffs has been slight. Only the less stable minerals, such as the ferromagnesians, have undergone chemical alteration. Even this alteration has not been intense, and consists in their replacement by small amounts of chlorite and serpentine.

Although generally only slightly altered, the Metchosin volcanics have been intensely contact-metamorphosed in the neighbourhood of the intrusions of Sooke gabbro, and this is particularly true of the basalts and tuffs exposed on the Sunloch and Vulcan mineral claims. Clapp[1] says of this contact metamorphism:

"The contact zones are seldom more than 200 to 300 feet in width and are frequently narrower, although in a few places, especially along sheared zones, the contact-metamorphosed and mineralized areas are found at distances of a mile or more from any outcrop of the intrusives. Where less metamorphosed the original texture of the basalt is partially preserved since the feldspars remain unaltered and form diversely to subradially arranged laths set in a fine-grained lustrous groundmass which is clearly seen.. .. .. .. to consist largely of hornblende. On microscopic examination the original ophitic structure is conspicuous, but the augite is in most rocks replaced by a light sage to brownish green, weakly pleochroic fibrous to almost compact hornblende. The brownish and more compact hornblende is very similar to that developed in the Sooke gabbro itself, and in a few places forms large poikilitic crystals. In the more metamorphosed rocks the original ophitic texture is less conspicuous and irregular areas of actinolite and chlorite, as well as of uralite have been developed, and veinlets and replacements of epidote and zoisite are common. The feldspars remain unchanged. The more metamorphosed rocks have been impregnated with finely crystalline pyrite, pyrrhotite, and chalcopyrite and also replaced and cut by veinlets of these minerals. These metallic minerals are seldom abundant except in sheared zones in the contact-metamorphosed rocks. Some of the shear zones are, however, highly metamorphosed and in them are numerous prospects. The sheared and mineralized rocks consist largely of aggregates of secondary minerals, chiefly hornblende, actinolite, epidote, chlorite, quartz, and secondary feldspar, cut by veinlets of quartz and epidote. The metallic minerals have developed late in the metamorphism of the rocks, and occur disseminated through the earlier secondary minerals, and in veinlets and irregular replacements, usually associated with quartz, cutting the earlier quartz epidote veins."

Metchosin Basalts in the Vicinity of the Sunloch Deposits. In the vicinity of the Sunloch and adjoining claims the Metchosin volcanics are both sheared and intruded by a considerable mass of gabbro and are in consequence metamorphosed to such a degree that the original character of the rocks is almost obliterated. In their original condition, no doubt, they were similar to many of the unaltered types found in the Sooke area and described briefly in a preceding paragraph, but all the volcanic rocks examined, and included in the accompanying map, are now metamorphosed by contact and dynamic action. They are composed of greenish and brownish hornblende, labradorite, occasionally augite and small amounts of magnetite, pyrite, chalcopyrite, and veinlets of quartz, epidote, zoisite, chlorite, calcite, and sericite.

Of these minerals the hornblende is the most abundant, forming from 50 per cent to 90 per cent of the rock. Two varieties were observed, a greenish brown hornblende, giving pleochroic shades of brownish green to yellowish green, and a deeper green variety, giving shades from light green to deep bluish green, the latter often forming veinlets which cut the brownish hornblende, as well as the labradorite and other minerals. The brownish hornblende is closely associated with small grains of

[1] Clapp, C. H., Geol. Surv., Can., Mem. 96, p. 270.

augite and bears the same relation to the feldspars as the augite does in the less altered basalts. It is, therefore, believed to have been formed from the alteration of primary augite. The feldspar forms from 5 to 20 per cent of the specimens examined and occurs both as laths and well developed tabular crystals, which are more than ordinarily inclined to idiomorphism. It ranges in composition from rather basic labradorite to bytownite, the former predominating. It is usually characterized by very fine twinning lamellæ, formed by both the albite and pericline laws. It is comparatively little altered, but in places was observed to be replaced by sericite, chlorite, quartz, and actinolite. In the basalts of this vicinity augite is an extremely rare constituent, and in all the basalts that were collected in the neighbourhood of the mine only a few scattered grains of augite were noted, due probably to its alteration to hornblende. These were either small interstitial grains or larger allotriomorphic crystals enclosing blades of labradorite. All the secondary minerals, excepting the hornblende, occur in very small amounts. Quartz is on the whole the most abundant of the minerals, but is confined altogether to the vicinity of quartz veins and areas of basalt that have been extensively sheared. In these areas it is very abundantly disseminated in certain light coloured, gneissic-looking bands. Epidote is not so plentiful as one would expect in such highly altered volcanic rocks and is seen only in very small veins associated with quartz and sulphides. The sulphides—chalcopyrite, pyrrhotite, and pyrite—are sporadic in their occurrence and irregularly distributed. They are, however, largely confined to areas in the vicinity of the gabbro contacts that have undergone considerable shearing, and it is in such areas that the commercial ore-bodies of these deposits are developed.

Structure. The Metchosin formation consists of a series of superimposed lava flows and beds of tuff ranging in thickness from 2 or 3 feet to 300 feet. As is always the case in such volcanic series the conformity existing between the beds is by no means perfect and many large irregularities occur in the planes of contact. Owing to such irregularities and to the difficulty of distinguishing the various flows, because of lithological similarity and metamorphism, the structure of the formation is not easily determined. In places, however, where cherty tuffs are exposed, or where the lava flows are thin, folding was observed and is found to have taken place along axes which strike north 60 degrees to 70 degrees west. The prevailing dips are to the northeast, and Clapp[1] cites evidence which leads him to the conclusion that the part of this formation occupying the Sooke sheet forms a part of the southern limb of a geosyncline.

Besides this general folding on a large scale, local intense folding is observable, which is thought to be confined to the more incompetent beds. These minor folds have strikes approximating the direction of the main folds, but having more variable dips.

Shearing has been extensively developed in the Metchosin basalts along the great fault which bounds them on the north and to a lesser degree in the vicinity of the gabbro intrusives. As will be pointed out later, the shearing has an important bearing on the development of the mineral deposits of the district.

Sooke Gabbro.

General Character and Distribution. The gabbro mass exposed in the vicinity of the Sunloch and Vulcan mineral claims is considerably altered and its original character to a great extent obliterated, but in its present state of metamorphism it very strikingly resembles the metamorphosed parts of the Sooke gabbro and has the same relation to the Metchosin basalts.

This formation has been described in great detail by H. C. Cooke[2], of the Geological Survey.

The formation exposed in the Sooke map-area consists of five small bodies, the largest of which, occupying the East Sooke peninsula, forms an elliptical mass about

[1] Clapp, C. H., Geol. Surv., Can., Mem. 96.

[2] Cooke, H. C., "Gabbros of East Sooke and Rocky point," Geol. Surv., Can., Mus. Bull. 30, 1919.

5 miles in length. The only known occurrence outside the Sooke and Duncan map-area is the one on the Sunloch claims, situated about 3 miles west of the boundary of that area.

These small stocks, besides being sheared and highly altered by mineralizing solutions, have undergone considerable magmatic differentiation, with the result that they now present a great variety of rock types. Cooke describes the four following types: olivine gabbro, augite gabbro, anorthosite, and granite, and it is probable, from its resemblance, that the Sunloch gabbro is a representative of the olivine gabbro in a state of intense alteration.

The olivine gabbro, as described by Cooke, is a medium, coarse-grained, grey to black rock, consisting approximately of 45 per cent to 50 per cent of bytownite feldspar, about the same amount of augite, 5 per cent of olivine, and 1 per cent of ilmenite, but so irregular in composition that within short distances the above proportions may vary between wide limits. In its altered condition it carries from 50 per cent to 100 per cent of hornblende.

The Sunloch meta-gabbro, an altered phase of the Sooke gabbro, is a black, irregularly grained rock, consisting of 10 per cent to 45 per cent labradorite-bytownite feldspar, 50 per cent to 100 per cent hornblende, a very small amount of augite, and a few grains of ilmenite, magnetite, and titanite. No olivine was observed in the material collected. The almost total absence of augite is due to its alteration to hornblende, a change which took place before the rock was noticeably fractured and invaded by mineralizing solutions. The result of this early action on the augite is the development of a pale green, fibrous hornblende, strongly pleochroic from pale green to yellowish green. Several grains of augite in a partly altered state were observed. At a much later period the gabbro was strongly fractured and attacked by solutions which deposited great quantities of greenish brown hornblende as veinlets cutting the feldspars, augite, and the pale green hornblende. Another variety of hornblende, of yellowish brown colour, probably titaniferous, is thought to be a primary constituent.

Structure. The gabbro masses intrusive into the Metchosin basalts and exposed in the Sooke map-area, are elongated along two parallel axes which conform to the direction of the main folding, i.e., north 60 degrees to 70 degrees west. The projection of the southern axis in a westerly direction beyond the boundary of the Sooke map-area would pass close to the Sunloch claims. It is, therefore, probable that the gabbro mass exposed on the Sunloch claims is a part of the large body presumably underlying the greater part of the Sooke map-area and with which the other stocks outcropping in the area are connected in depth. The Sunloch mass, in so far as it has been mapped, has two nearly parallel boundaries and would, therefore, be classed as a dyke rather than a boss or stock. Its northern contact, as exposed in the canyon of Jordan river, has a nearly vertical dip to the north. The southern contact is also nearly vertical, but more irregular than the northern.

ORE DEPOSITS.

Distribution. Copper deposits occur on or near both contacts of the Sunloch gabbro dyke. About 300 feet beyond the northeast contact are several ore-bodies of the Sunloch group. On the southwestern contact where it crosses the river are several showings belonging to the Vulcan group of claims, and where this contact reaches Sinn Fein creek are the showings of the Black Hornet claim.

The Vulcan and Black Hornet deposits had not, up to the time of examination, been developed to any extent, and little can be said concerning them, except that the surface showings are strong and worth exploring.

Structure of the Ore Deposits. A recognition of the structure obtaining in the country rocks is an important need in development work. The significant feature, which is shown on Figure 2, is: the bedding planes within a few miles of the deposit strike from north 60 degrees west to north 90 degrees west and dip from 60 degrees to 90 degrees in a northerly direction.

The probable trend of the axes along which the gabbro has been intruded is parallel to the main axis of folding in the basalts. The Sunloch gabbro, however, in the vicinity of the deposits, strikes north 50 degrees west and, therefore, cuts the bedding planes at an angle of about 30 degrees.

A pronounced schistosity has been developed in the basalt close to and parallel to the contacts of the gabbro. The basalts are cut also by a series of small faults striking north 10 degrees east to north 40 degrees east which are, therefore, nearly at right angles to the strike of the bedding planes. These faults are all small with throws of not more than a few feet and were mostly, if not all, formed prior to the periods of ore deposition.

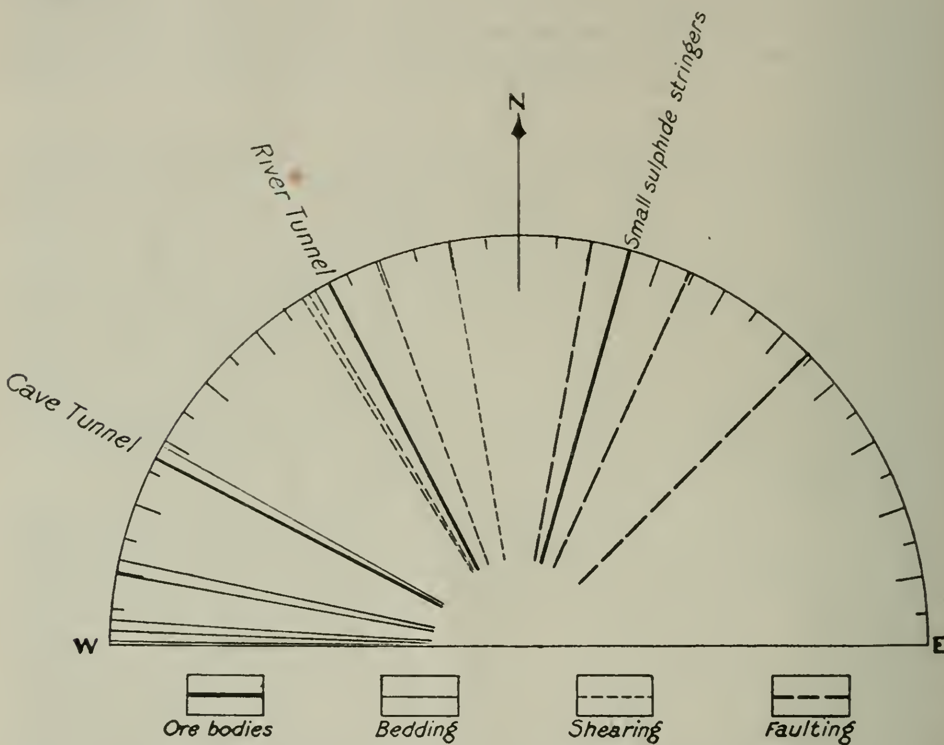

Figure 2. Diagram showing the relationship of the ore-bodies to the bedding, shearing, and faulting, Sunloch copper deposits, Jordan river, Vancouver island, B.C.

A persistent set of closely spaced joints was observed in the tunnels, one group of which strikes north 30 degrees west and dips 80 degrees to the northeast, and the other group strikes north 55 degrees east and dips 83 degrees to the northwest.

Since the planes of schistosity are the most pronounced lines of weakness in the rocks they have provided the easiest channels for ore solutions and the largest and most promising ore-bodies are consequently developed in them.

The planes of bedding are another determining factor in the location of smaller deposits than those formed in the planes of schistosity; but because of the irregularity of these planes the ore-bodies formed in them are more irregular in size and direction. Such a deposit is that exposed in the Cave tunnel. A third set of ore-shoots, which are scarcely more than stringers, follows directions somewhat parallel to the faulting, but the stringers are too small to be of any value.

A projection of the two main ore-bodies along the strike indicates an intersection at a distance of about 1,000 feet and if mineralization occurs at this point, an ore-

body larger than any yet discovered may be present, which would strike in the direction of the river zone and pitch to the northwest at an angle greater than 80 degrees.

Some of the more competent beds of volcanic rock are not sheared. These beds are devoid of mineralization and it is one of these competent beds which defines the northern boundary of the river zone. It has a steep dip to the north and conforms to the dips of the other beds in the vicinity.

The Ore. In hand specimens the ore consists of a sheared and hornblenditized basalt containing either a large proportion of finely disseminated chalcopyrite, or a smaller amount of chalcopyrite distributed in a network of small, filmy veinlets. Veinlets of either quartz and epidote carrying pyrite and chalcopyrite, or aplitic material, are occasionally seen. Alternating layers of rich and lean ore produce a banded appearance in the deposit. The ore is invariably finely granular, and large masses of pure sulphides are rarely seen. Small grains of pyrite are plentifully distributed throughout the ore.

The composition of the Sunloch ore is simple. The following is a complete list of the minerals, named in order of deposition: magnetite, hornblende, aplite, quartz, epidote, pyrite, molybdenite, chalcopyrite, limonite, and chalcocite.

The magnetite is rare and occurs both in the ore and country rock, of which it is probably a primary constituent.

The hornblende is very abundant and was introduced at two different periods, the first soon after the intrusion of the gabbro when the augite was completely replaced by hornblende, and the second at a much later time and after some, at least, of the chalcopyrite had been deposited. This later hornblende is a deeper green variety associated with considerable actinolite and appears in the form of minute veinlets cutting the earlier hornblende as well as the pyrite and chalcopyrite.

The small aplite stringers were formed during the early period of alteration and are cut by other veinlets carrying quartz, epidote, pyrite, and chalcopyrite.

The pyrite is in general much earlier than, and extensively replaced by, the chalcopyrite; but a small amount was introduced at a very late date in the periods of mineralization and occurs in the form of minute stringers of pyrite cutting all the other minerals excepting the limonite and chalcocite. Such late stringers of pyrite are, however, rare in ore of this class.

The deposition of the chalcopyrite was spread over a long and uninterrupted period, during which small quantities of molybdenite were also deposited.

The limonite is due to oxidation at a recent period and is found only in small amounts usually associated with pyrite rather than with chalcopyrite.

The chalcocite is probably of secondary origin and of a very recent period. It occurs in quantities much too small to have any commercial influence on the value of the ore.

Sunloch Ore-bodies.

On the Sunloch property there are three ore zones roughly parallel and approximately 300 feet apart. The most southerly, namely, the Cave ore zone, is about 400 feet north of the gabbro contact; the most northerly is the River zone, and between these lies the Archibald showing.

The River zone is the most important of the three, and, consequently, has been the most extensively developed. It is exposed at the surface in several good outcrops in the immediate vicinity of the portal and at several points to the north of the tunnel on the same side of the river. Several small stringers were found in the stream bed in a search for the extension of the ore-body across the river, but on the opposite bank no definite indication of its continuation had been found up to the time of this examination, though the search was being carried on with vigour. A tunnel, 720 feet in length at the time of the examination, had been driven along the strike of the ore-body and exposed, except for a short distance in from the portal, an almost continuous body of ore carrying between 3 per cent and 4 per cent copper and small values in gold. The

width of the zone has been tested by a crosscut at a point 240 feet in from the portal and also by two drill holes. The crosscut exposed 15 or 16 feet of ore averaging 3·7 per cent copper, and also a small zone 3 feet wide of 3·8 per cent ore separated from the larger body by 6 feet of barren rock. The diamond drill hole has proved this ore to a depth of 120 feet below the tunnel, and since the face of the tunnel is now about 440 feet vertically below the surface, the perpendicular dimension of the zone must be quite large. Though the extension of this zone across the river has not been proved, its continuation in the opposite direction for a considerable distance beyond the present face of the tunnel (which is in good ore) is highly probable. This zone is exposed also in a small crosscut tunnel 100 feet northeast of the portal of the River tunnel. This tunnel is on a continuation of the main ore-shoot of this zone and samples taken from it gave 2·5 per cent copper.

The Cave ore zone is more irregular, and, therefore, more difficult to follow and to outline. Its irregularity is probably due to the fact that it follows, in part at least, one of the irregular bedding planes between two flows of basalt, rather than the shear zones which are more uniform in strike and dip.

The tunnel was begun on an excellent surface showing and was driven 180 feet in a south 75 degrees east direction, the first 60 feet passing through ore averaging about 4 per cent copper. At 180 feet from the portal a crosscut was driven south 10 degrees west for a distance of 190 feet. The first 60 feet of the crosscut, 10 feet of which averaged 1·3 per cent copper, passed through low grade ore averaging 0·9 per cent copper. The next 20 feet encountered unmineralized rock and beyond this occurs 36 feet of ore averaging 2·58 per cent, one section of which averaged 5·1 per cent copper for a distance of 11 feet. For the remaining distance the tunnel passed through low grade ore.

At the point where the crosscut encountered the rich streak, a drift was driven south 60 degrees east for a distance of 200 feet, passing through good ore for the most part. It ends, however, in low grade ore, and small crosscuts driven short distances in both directions failed to locate any good ore. No work is being done at present on this ore-body.

About midway between the River and Cave zones outcrops of good ore, known as the Archibald showings, were discovered at an elevation of 260 feet above the levels of the tunnels. A diamond drill hole connecting the two tunnels underneath these showings proved the presence of 2 feet of 4 per cent ore and 10 to 12 feet of low grade material.

A crosscut was driven from the river tunnel to this ore and encountered better ore than was inferred from the values given by the drill cores. A drift a few feet in length has been driven on this ore.

Summary and Conclusions.

Geologic History and Origin of the Deposits. The salient facts brought out in the preceding description, and upon which the conclusions are based, are the following:

The deposits occur in the Metchosin formation, a series of basic lava flows and tuffs which were extruded in early Tertiary times.

These volcanic rocks were compressed into large folds striking north 60 degrees to 70 degrees west and have dips varying from zero to 85 degrees. The greater part of the formation exposed in the district forms the southern limb of a geosyncline and consequently dips to the northeast. The folding was accompanied by considerable fracturing in the less competent beds.

In the middle Tertiary the Metchosin formation was intruded by a number of stocks and dykes of coarse, basic, gabbro which appear to have invaded the volcanics along two principal axes of folding, the southern of which passes through the Sunloch property.

These intrusions had a profound metamorphic action on the volcanic rocks adjacent to them. A pronounced shearing was developed roughly parallel to the con-

tacts. The augite was replaced by hornblende so that great quantities of this mineral developed in the volcanics, and in parts of the gabbro itself, by solutions emanating from the interior parts of the gabbro and invading the volcanic rocks chiefly along shear and bedding planes.

Following these solutions were others which deposited more hornblende, actinolite, aplite, epidote, quartz, pyrite, molybdenite, and chalcopyrite, the last in sufficient quantity to form commercial ore-shoots.

In very recent times oxidation to a slight extent has taken place, producing small amounts of limonite and chalcocite.

Status of the Sunloch Property. It will be seen from the descriptions of these ore deposits that a considerable tonnage of commercial ore has already been proved on this property and that, as yet, only part of the possible ore-bearing ground has been tested.

In his report to the company at the end of 1918, the managing director, Mr. R. H. Stewart, estimated that from 100,000 to 150,000 tons of ore, averaging 3 per cent to 5 per cent, had up to that time been proved. This estimate was based on actual measurements and numerous assays and should be nearly correct. Since that time development work has been continued with some success so that the above quantity has been materially increased.

Regarding future possibilities, it is the writer's opinion that the ore-body exposed in the River tunnel will continue in a southeasterly direction for a considerable distance, possibly as far again, beyond the present face of the tunnel. The ore will in all probability continue to a great depth below the present workings, possibly until the gabbro is reached and beyond, though not without variations in size and tenor. It does not seem to continue in a northwesterly direction.

The ore-body in the Cave tunnel appears to cease at the face of the present workings, but since it is a very irregular ore-body it may be found to regain its strength at some distance beyond the present face. Good showings, which might prove to be a continuation of this ore-body, occur on the opposite side of the river. The Cave ore zone will persist with depth, but owing to its irregular nature may be difficult to follow.

The Archibald zone has possibilities, but not as great as the other two.

It must be borne in mind that this deposit belongs to a class which is commonly found in the coast section of British Columbia, i.e. the class which consists of disseminations or small veins of ore formed in volcanic rocks at the contacts of plutonic intrusives, and which have been frequently very disappointing. They usually consist of disseminated bodies that are too low grade, or of veins which are too small, the reasons being that the impervious nature of ordinary volcanic rocks, and their high degree of chemical inertness resist the tendency to replacement by the mineralizing solutions. These two disadvantages, however, have been to some extent removed in the case of the Sunloch deposit by the shearing which has made the volcanics more pervious and by the presence of such unusually large quantities of hornblende which lends itself to the process of replacement more readily than the minerals usually found in volcanic rocks. It is for these reasons that the ore deposits of this district are found to be invariably confined to sheared and hornblenditized rocks.

It must also be remembered that the formations associated with these deposits are not developed on a very large scale, being confined to only a few hundred square miles, and that, therefore, the ore deposits in them cannot be expected to rank with the great ore deposits associated with continent wide formations; and again that the other similar copper deposits associated with these formations have all, up to the present, been proved to be quite limited in extent. From these considerations and even

though there are 150,000 tons of ore proved already on the Sunloch property and another 100,000 tons of probable ore, yet one would expect the deposit to have a tonnage measured in the hundreds of thousands or a few millions at most. In other words it is a good deposit of moderate rather than great size.

COQUIHALLA MAP-AREA, B.C.

By Charles Camsell.

CONTENTS.

INTRODUCTION.

The Coquihalla map-area comprises a strip of country extending from the town of Hope on Fraser river up the valley of Coquihalla river as far as Boston Bar creek and takes in a belt from 4 to 10 miles deep on either side of the river.

The Kettle Valley railway runs through this strip of country and all the territory embraced by the map-area is tributary to that railway.

A topographic base map of this area was made by F. S. Falconer in the season of 1918, on a scale of 1 mile to 1 inch with contour intervals of 100 feet.

Owing to the pressure of other duties it was found impossible to spend more than four weeks in the field, on geological mapping, and, since the area is very difficult to cover on account of high relief, dense forest, and lack of trails, only a very small part of the work necessary to a full report was done.

Placer gold has been mined in early days on Coquihalla river and more recently lode gold deposits have been developed that are very high grade.

Other deposits of gold, silver, lead, and copper occur in territory immediately adjacent to the area, namely, on Silver creek, Siwash creek, Tulameen river, and elsewhere; but the area itself is distinctly a gold-bearing one and deposits of this metal are likely to be the most important developed in it.

The mapping of the area was undertaken with a view to providing accurate structural and other geological data on which plans for prospecting and development might be based. At the same time prospectors have frequently been urged by the writer to confine these efforts to districts in which transportation either by rail or water is already provided and to do intensive detailed prospecting in such districts rather than to go into more remote regions where little or no transportation facilities exist.

Coquihalla area is a district where rail transportation has only recently been provided, by the Kettle Valley railway, but which has remained unprospected up to recent years owing to the physical difficulties that confront the prospector in any attempts to carry on his work.

The limited knowledge of the geology of the area was, however, sufficient to recommend it to the prospector because of the occurrence of gold-bearing quartz veins in the adjacent Siwash Creek district where the same association of geological formations occurs as in the Coquihalla area.

The valley of Coquihalla river is one of the oldest routes of travel from the coast to the interior of British Columbia, but it has not been largely used owing to the difficulty of maintaining a trail. The valley is now traversed from one end to the other by the Kettle Valley railway, but although surveys were made by the Canadian Pacific Railway Company over forty years ago only a very poor pack trail existed from that time up to the time when the Kettle Valley railway was completed, and in the building of the railway this trail was destroyed and has not been rebuilt. There is, therefore, at the present time, no means of travel along the valley except by rail.

Lode prospecting began in the area about 1911, at the time of the gold excitement at Steamboat mountain on Skagit river. A stimulus was given the following year when construction of the Kettle Valley railway began and a number of gold quartz claims were staked in the basin of Ladner creek and on the divide between Ladner and Siwash creeks. Some of these deposits proved to be very rich and on one property mining on a small scale was begun.

From this property, the Emancipation group, about 90 tons of gold ore have been shipped to the smelter at Tacoma which returned to the owners about $35,000 after all charges had been paid.

A considerable number of other claims have been staked, but little development work has yet been done.

The town of Hope, situated in the southwestern corner of the area at the junction of Coquihalla river and the Fraser, is about 100 miles east of Vancouver and is connected with that city by both the Canadian Pacific railway and the Canadian National railways. The town supports a population of about 200 people and is the only place of any importance in the area. A shingle mill at Jessica gives employment to a small additional number of people.

Previous to the present survey of the area the only geological investigation was that made by G. M. Dawson in the summer of 1877 when he made a reconnaisance through Coquihalla valley from the summit down to Hope. On this trip Dr. Dawson defined the main geological formations and made some notes on the structure and stratigraphy of the sedimentary rocks. His observations are recorded in the Report of Progress of the Geological Survey for the year 1877-1878.

GENERAL CHARACTER OF THE DISTRICT.

The whole area is a mountainous region embraced within the limits of the Cascade Mountain system. A western prolongation of this system crosses the International Boundary line between longitudes 121 degrees and 122 degrees and extends northward along the eastern side of Fraser river as far as Thompson river. The Coquihalla area lies on the western side of this prolongation.

The area consequently has an extremely rugged topography with a relief ranging from 160 feet to 7,500 feet above sea-level. The valleys are deeply cut into this terrane and their sides are steep and frequently occupied by bare rock cliffs which for hundreds of feet break the evenness of the slopes. The summits that do not exceed 6,000 feet in altitude are usually rounded and dome-shaped as a result of continental glaciation, but those that project above that level are sharply terminated peaks frequently holding small mountain glaciers on their northern flanks.

A very dense forest growth of fir, cedar, hemlock, and spruce covers all the country up to a level of 6,500 feet above sea-level.

Above the mouth of Ladner creek the valley of the Coquihalla is narrow and steep-sided with practically no bottom flats. The river has a grade of about 120 feet to the mile and it works its way down with difficulty through narrow canyons and huge masses of rock that have broken from the precipitous sides. Below Ladner creek the valley widens considerably, the grade lessens to about 70 feet to the mile, and the stream is bordered on either side by flats about a quarter of a mile wide.

At Othello the course of the stream has been diverted from its ancient pre-glacial channel by accumulations of glacial material that now fill, to a depth of 500 feet, the

old channel which formerly carried the Coquihalla waters through to Fraser river by way of Kawkawa lake. The stream now takes a sharp turn to the southeast through a very narrow box canyon and after joining the Nicolum, flows around the south side of an isolated hill about 900 feet high. At its junction with Fraser river the Coquihalla has built up a broad, flat delta on which the town of Hope now stands.

The streams tributary to the Coquihalla have exceedingly steep grades and plunge downwards to the master stream over falls or through narrow rock-walled canyons. Their valley sides are exceedingly steep and any attempt to ascend these valleys is a difficult undertaking, for virtually the only trail up any of these tributaries is that running up Dewdney creek.

The annual precipitation in this area is very heavy, particularly in winter when it occurs in the form of snow; and since the valley slopes are very steep snowslides are of frequent occurrence in the winter and early spring months. Great difficulty has consequently been experienced by the railway company in keeping the road in continuous operation. In spite of the heavy precipitation practically all the winter's snowfall is carried away each year by the streams and little of it remains to form permanent snow or ice fields. Those that do exist are small mountain glaciers which lie in basins on the northern slopes of the mountains.

The dense forest and steep hillsides make travelling and prospecting difficult, and the few trails that traverse the country have been hard to build and are difficult to maintain. Besides the transportation provided by the railway, a good, well travelled trail, known as the Dewdney trail, runs up Nicolum river towards Princeton; a new trail has been built up Ladner creek, and an old trail, which crosses the Coquihalla by a good bridge, runs up Dewdney creek and across the divide to Tulameen valley.

GENERAL GEOLOGY.

Coquihalla area contains rocks referable to two major geological formations, namely, the granitic rocks of the Coast Range batholith, and a series of older stratified rocks that have been intruded by the batholith. In addition, a small, unimportant area of conglomerate belonging presumably to the Lower Cretaceous is exposed on the west side of Fraser river at the end of the railway bridge.

Spread over these rocks in the lower part of the area is a varying thickness of Glacial and Recent material.

These geological formations may be summarized as follows:

Glacial and Recent deposits.
Lower Cretaceous.
Coast Range batholithic rocks.
Pre-batholithic rocks.

Pre-batholithic Rocks.

Rocks older than the granitic rocks of the Coast Range batholith are exposed in the valley of Coquihalla river from the mouth of Anderson creek to Boston Bar creek and they appear to occupy most of the region back from the valley between these two points. Smaller detached areas occur near Hope on either side of Fraser river.

This older series of rocks is made up of black slates, grey quartzites—some bands of which are cherty—schists, narrow bands of limestone, and some serpentine. The beds have an average general trend of north 20 degrees west with a dip to the southwest of 30 degrees or more. The persistent southwesterly dip would appear to indicate a monoclinal structure for the whole series, but there is other evidence, which Dawson noted, to suggest a general synclinal structure containing minor folds with a consequent repetition of some of the beds.

The series is intruded by granitic rocks, large areas of which lie to the north and south of the district as well as to the westward on Fraser river.

These rocks were described by G. M. Dawson in 1877 and correlated with the Boston Bar series exposed on Fraser river at North Bend. Rocks of a similar litho-

logical character occurring on Texas creek and Cayoosh creek were also correlated by Dawson with the Boston Bar series and in the absence of palæontological evidence he referred these various exposures to a Lower Carboniferous age, correlating them with the Lower Cache Creek rocks.

In the light of more recent work, however, this reference to a Carboniferous age would seem to require modification. The Boston Bar series at North Bend was found by N. L. Bowen, in 1912, to contain Mesozoic fossils of Jurassic or Triassic age[1]. There is no reason to doubt the correctness of Dawson's conclusions that the Boston Bar series at North Bend is equivalent in age to part, at least, of the series exposed on Coquihalla river, and that part, therefore, should also be considered as of Mesozoic age. The section, however, is very thick and probably, when studied in detail, Palæozoic rocks will be represented in it.

The same series of rocks is represented in the basin of Siwash creek on the Fraser River slope, where they are described by A. M. Bateman[2] under the name Siwash series and correlated with the Lower Cache Creek formation.

Coast Range Batholithic Rocks.

The granitic rocks are exposed in the Coquihalla valley near the mouth of Boston Bar creek and from the mouth of Anderson creek to Fraser river. They also extend some distance up the Nicolum, and both up and down the valley of Fraser river.

They consist mainly of granodiorite, but include more acid as well as more basic types which, however, do not differ greatly in time of intrusion. The larger areas are medium to coarse-grained and occasionally foliated. The small areas are frequently finer in grain. These rocks are intrusive into the slates, quartzites, etc., just described and are responsible for considerable contact metamorphism and the formation of such mineral deposits as occur in them.

Lower Cretaceous.

This formation is represented by a small area of conglomerate exposed on the west bank of Fraser river at the railway bridge. It is part of what was formerly a much larger area, the remnants of which occur along a north and south line running through Haig station. The conglomerate contains pebbles and boulders of quartz, granite, granodiorite, slate, and volcanic rocks, and is traversed by narrow streaks of sandstone. At the bridge it rests on granodiorite, but farther north it lies unconformably on top of highly disturbed slates of pre-batholithic age. It is consequently younger than both these formations. The position of this conglomerate in the bottom of Fraser valley, with high mountains of older rocks on either side, can only be satisfactorily explained by down-faulting along a north and south line, a line which was afterwards followed by Fraser river in cutting out its valley.

Glacial and Recent Deposits.

Owing to the mountainous character of the country and the steepness of the slopes Glacial and Recent deposits are not abundant. Glacial and fluvioglacial deposits at one time filled the Coquihalla valley to a depth of 400 or 500 feet, but these have been very largely removed by the action of the present stream. In the valley that joins Kawkawa lake to Coquihalla valley at Othello station, a great accumulation of morainal material still remains. This has a thickness of at least 500 feet and its deposition at that point was the cause of the diversion of Coquihalla river from the valley into its present course below Othello and the consequent cutting of the gorge in that position.

The flat land on which the town of Hope stands is of recent origin and has been built up by material carried there by Coquihalla river.

[1] Twelfth Internat. Geol. Cong., Guide Book No. 8, pt. 2, p. 266.

[2] Geol. Surv., Can., Sum. Rept., 1911, p. 126.

MINERAL DEPOSITS.

The only mineral of economic importance so far produced from the Coquihalla area is gold. Recovery of this metal was first made in a small way from the gravels of the streams, but more recently a small production has been made from lode deposits.

The original source of the gold, not only of the lode deposits but probably also of the placer, is believed to be in the belt of slates which strikes across from Jessica in a north 20 degrees west direction to the head of the south fork of Siwash creek and down that fork to the main stream. The gold-bearing character of this band of rocks was recognized years ago by Dawson and it is to this series of rocks that he refers when he states that "one point of particular interest with respect to the schistose and slaty rocks of the Boston Bar series and their representatives in the area of the present map, is their auriferous character".[1]

Gold occurs in this belt of rocks on Siwash creek, where the rocks cross Fraser river near North Bend, and on Cayoosh creek. At all those localities the rocks are in more or less close contact with the granite rocks of the Coast Range batholith or its offshoots and it is, probably, to this intrusion as well as to the chemical character of the slates that the occurrence of the gold deposits is due. This band of rocks, then, from Coquihalla river to Cayoosh creek, represents a gold-bearing zone which it would be well for prospectors to examine carefully in their search for gold deposits.

The gold deposits so far discovered are situated along a line extending from the mouth of Dewdney creek northwestward towards the bend of Siwash creek. Three principal groups of claims, namely, the Emancipation, O'Connell, and Idaho groups, have been located along this line. All these deposits have similar characteristics and belong to the same type of deposits.

The deposits lie in the slates and consist of bedded quartz veins which strike and dip with the rock formation. In many places the veins are well defined and have sharp boundaries, but occasionally the deposit occupies a fractured zone in which fragments of the country rock are separated from each other by reticulating veins of quartz, making an ore zone in many places several feet wide.

The deposits have apparently been formed at comparatively shallow depths. They are sparingly mineralized by pyrite and arsenopyrite and some enargite and in many places contain visible gold. Free gold can usually be obtained by panning the decomposed surface of the veins and discovery of the deposits has invariably been made by tracing the gold up the gulches to the outcrop by panning. The width of the veins varies from a few inches to, in one case, 8 feet, but little is as yet known of their persistence in strike and in depth. Values vary widely and are concentrated in definite shoots, leaving the other parts of the veins relatively low grade or barren.

Sufficient development has not yet been done to make it possible to work out the causes of the localization of the values or the factors governing the presence of the shoots in particular parts of the veins.

Gold is practically the only valuable metal in the veins and in its distribution it appears to favour one wall or the other or to have been deposited around fragments of country rock that remain in the veins.

Although considerable development has been done on the deposits of this belt, which lie on the Siwash Creek slope, only one property—the Emancipation—on the Coquihalla side has as yet produced any gold.

Idaho Group.

This group, consisting of four claims, is situated on the South Fork of Ladner creek at an elevation of 3,400 feet, the owners being A. E. Raab, J. Bailey, and T. Angelus. The group contains several outcrops of veins which were discovered by

[1] Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 44B.

tracing the gold up a small gulch by panning. The various outcrops represent probably three leads, one of which crosscuts the slates and the others run parallel to them. Both of the bedded veins strike about north 70 degrees west and dip to the northward at high angles. They have been traced by outcroppings down the gulch for a distance of several hundred feet, with a difference in elevation between the upper and the lower outcrops of 250 feet. These veins are from 3 feet to 10 feet or more in width and contain a little pyrite in a quartz gangue, the outcrop of which contains a gossan which on panning yields gold in very fine particles. Assays of the fresh rock are said to run from $7 to $14 per ton. The development work consists entirely of surface stripping.

O'Connell Group.

This group adjoins the Idaho on the lower side of the same slope. The main outcrop is at 2,900 feet elevation, where a tunnel 30 feet in length has been driven on a quartz vein which strikes north 70 degrees west and dips to the northward at an angle of 30 degrees. The vein is about 10 feet wide, well defined, and mineralized sparingly by pyrite and arsenopyrite. The gold here appears to be associated with the arsenopyrite, but can be obtained by panning on the decomposed outcrop.

Emancipation Mine.

This mine is situated on the western slope of Coquihalla valley opposite the mouth of Dewdney creek, at an elevation above sea of 2,600 feet or 1,100 feet above the railway. The claims were staked about six years ago and are owned by Messrs. Merrick, Thompson, and Beach. A good pack trail connects the mine with the railway.

As described by Brewer[1], the first work done on this property was on a big quartz lead carrying low values in gold. Later work, however, was confined to a high grade vein near the hanging-wall of the large vein. On this a tunnel has been driven about 220 feet, with a crosscut 80 feet in length to the right at a point 70 feet from the portal. A raise to the surface and a winze 50 feet in depth were made on the ore-shoot about 100 feet in. This raise and winze supplied all the ore shipped, namely, about 90 tons which yielded $35,000 in returns.

The vein is in black or calcareous slates and strikes north 20 degrees west and dips to the westward at an angle of 30 degrees. The width varies from 1 to 3 feet. The vein carries pyrite and arsenopyrite, some enargite, and much free gold. The gold is associated with both of these minerals and with them impregnates the country rock adjacent to the vein. Polished specimens indicate that the gold was introduced later than the pyrite and arsenopyrite. Silver is shown, from assays, to be present in the proportion of 1 ounce of silver to 6 ounces of gold.

SILVER DEPOSITS AT STUMP LAKE, B.C.

By Charles Camsell.

Early in October a short visit was made to Stump lake to examine a group of silver deposits which were practically abandoned for about thirty years, but have recently been reopened. These deposits were originally staked in the early eighties and for seven or eight years active development was carried on and some ore shipped to Swansea, South Wales. Owing, however, to difficulties of transportation and the complex character of the ores, mining ceased about 1890 and claims that were not crown-granted were allowed to lapse. Four years ago the Donahue Mines Corporation bought a group of eight claims on Mineral hill on which considerable underground development work had been done, and last year other claims were taken up by R. R. Hedley on Scott creek.

[1] Ann. Rept. Minister of Mines, B.C., 1915, p. 257.

These claims have been actively developed during the late summer and some ore has been shipped to Trail. The Donahue Mines Corporation shipped 100 tons of picked ore from the dump in 1917 and then closed down. At the time of visit the Joshua shaft, which is over 400 feet deep, was being unwatered and had been drained to a depth of 360 feet.

R. R. Hedley, who is working the Mary Reynolds mine on Scott creek, shipped during 1919, 132 tons of sorted ore, yielding about $50 to the ton, from the main shaft, 100 feet in depth.

The geology and mineralogy of these deposits are fully described by G. M. Dawson in his report on the Kamloops map sheet[1], but it may be mentioned here that these deposits consist of quartz veins from 10 inches to 5 feet in width traversing a dark green diabase porphyrite and containing pyrite, chalcopyrite, galena, zinc blende, jamesonite and tetrahedrite. The values are mainly in silver with lesser amounts of gold, and where the mineralization by these minerals, especially tetrahedrite, is heavy, the silver content is very high, running over 400 ounces to the ton. The strike of the veins varies from north 20 degrees west to north 15 degrees east, and they have been traced on the surface for several hundred feet.

Regarding the number and probable value of these veins Dawson states that "the metalliferous veins already known in this somewhat limited district are numerous, and while it is probable, from their very number, that no individual lode will be found to possess great continuity, the work done is sufficient to show that a considerable permanent output of ore may be obtained."[2]

At the time of visit the only new development, other than that on the claims described by Dawson, had been done on the Mary Reynolds claim. Here in the 100-foot shaft, at a depth of 35 feet, drifts have been run to the north and south on a high-grade streak of ore. An audit tunnel was also driven on the vein 65 feet below the collar of the shaft with a raise to the 35-foot level, and from these workings all the recent shipments have been made. The vein is about 4 feet wide and contains a high-grade streak of ore from 4 to 18 inches wide on one wall or the other, which carries from $50 to $100 to the ton, mainly in silver, the gold content being from $3 to $5 to the ton. The remainder of the vein contains concentrating ore of considerably lower value. The vein minerals are pyrite, galena, tetrahedrite, and jamesonite, in a gangue of quartz and calcite. Near the surface are secondary ores of silver.

The veins of this district are of a type that have been formed at an intermediate depth by ascending thermal waters, probably in genetic connexion with an area of Jurassic granites lying to the westward of Stump lake. The paragenesis of the vein minerals, as determined by polished specimens, is apparently as follows: quartz, pyrite, zinc blende, tetrahedrite, chalcopyrite, galena, calcite.

CARIBOO DISTRICT, B.C.

By B. R. MacKay.

The field season, 1919, was limited to three months, July, August, and September. Of this time two months were spent in the Horsefly River area in studying and mapping placer deposits in Harpers camp, Black creek, and Horsefly Forks, in examining an oil-shale prospect on Antoine creek, and in visiting the neighbouring deposits at Twentymile creek, Bullion, and Keithley creek. The remaining month was spent in the Barkerville district in examining various placer deposits, and in visting the quartz ledges on Proserpine mountain.

[1] Geol. Surv., Can., Ann. Rept., 1894, p. 333 B.

[2] Ibid. p. 333B.

Throughout the work every assistance possible was rendered by the operators, mine officials, and residents of the district, and the writer expresses his sincere appreciation to all for the assistance and information which have been so cheerfully accorded him. Special acknowledgments are also due Mr. L. A. Dodd, Gold Commissioner of the district. During the season Messrs. W. G. Barrett, M. E. Hurst, and W. J. Wyllie were attached to the party as field assistants and rendered efficient service.

In the Cariboo district, as in other gold producing districts, the production continued to decline during the period of the world war. This decline was due largely to two factors, namely, lack of labour and increased cost of operation, while the price of the metal mined remained stationary. The latter factor was the more serious and resulted in the closing down of a number of the plants indefinitely.

As the present yearly production has been derived wholly from placer mines that were kept in operation throughout the war, the increase over last year is naturally very slight. The yearly returns, however, are not to be taken as an indication of the present condition of the camp. During the past season operations were resumed on plants which had been idle throughout the war, other property was acquired by new companies, returns from which will not be forthcoming for a couple of years, and there was as well considerable English and American capital seeking investment in favourable looking placer deposits. A marked renewal of interest has also been taken in the gold quartz properties, several groups of the most promising looking ledges of the Barkerville district having been bonded to a financially strong corporation which at present has a large staff of men on the ground engaged in stripping, tunnelling, and otherwise prospecting these veins. The outcome of this development work is being watched with much interest by both local and foreign capitalists, as the success of the undertaking will be a great incentive to the development of other favourable looking quartz ledges in the district, some of which have already been acquired by syndicates with the intention of undertaking development work next season. Altogether, a most optimistic attitude is shared by every operator in the district, and all are confident that once normal conditions are restored a new era of prosperity will dawn on this famous gold-bearing district.

The confidence in the future of the district is not inspired by any material increase in the yearly production or in the development work now in progress, but rather by the latent mineral wealth of the district in both placer and lode gold deposits as shown by the extent of undeveloped placer ground in comparison with that which has already been worked and which yielded such rich returns, and the numerous promising-looking quartz ledges which abound in the district. Although most of the easily accessible placer deposits have been exhausted there still remain numerous buried channels, the deposits of which have as yet never been touched. Before a large outlay of capital on these deposits is warranted, however, they should be subjected to a most careful examination.

With the completion of the Pacific Great Eastern railway to Quesnel, which road is now constructed beyond Williams lake, it will be possible to bring in dredging, pumping, hoisting, and other heavy machinery at a much lower cost than is at present possible. It is unfortunate, however, that the route of this railway does not pass through the mineralized belt of the Cariboo district, since for many years it has been fully appreciated that the great drawback to the mining industry of this district is the lack of railway communication, a most important factor in lowering the cost of production.

THE DISCOVERY OF FOSSILS IN THE MESOZOIC ROCKS OF HEDLEY, B.C.

By S. J. Schofield.

The sedimentary series exposed on Nickel Plate mountain (the "Striped mountain" of Dawson), in the vicinity of Hedley on Similkameen river, is shown by Dawson on his map of the southern interior of British Columbia issued in 1877. A general colour includes "the Palæozoic and Triassic (Cache Creek, Nicola series, etc.)" owing to the absence of organic remains and the similarity in lithology of the two series which prevented their separation in the field, although at this time Dawson had classified on fossiliferous evidence the Cache Creek series as Carboniferous, and the Nicola series as Triassic-Jurassic in other localities in the Interior Plateau. In the text of the report Dawson[1] gives a detailed description of the rocks exposed on Nickel Plate mountain and refers them provisionally to the Cache Creek group (Carboniferous). About 8 miles south of Hedley and a short distance above the Ashnola (Ashtnoulou of Dawson) river, he found fragments of limestone in the talus which "held obscure fossils some of which are minute branching tabulate corals, and lithologically precisely resemble those elsewhere known in association with quartzites similar to those of this locality and proved to be of Carboniferous date by their fossils". The section in descending order on Nickel Plate mountain is given by Dawson as follows:

	Feet.
1. Grey and red, siliceous and argillaceous beds..	300
2. Limestone, with some siliceous layers..	150
3. Grey and red, banded, siliceous and argillaceous beds..	600
	1050

In 1907, the ore deposits and geology of Nickel Plate mountain at Hedley were examined by Camsell[2], who, in the absence of organic remains, followed Dawson in classifying the sedimentary series of this locality as belonging to the Cache Creek group of Carboniferous age. Camsell recognized the presence of volcanic material present in the section exposed on Nickel Plate mountain as shown by the following section in descending order.

		Feet.
4 Aberdeen formation..	Interbanded limestones, quartzites, argillites, and volcanic materials..	3,000+
3. Red Mountain formation	Volcanic materials, tuffs, breccias...	1,200
2. Nickel Plate formation...	Massive limestones at the top (*Kington limestone*) and bottom (*Sunnyside limestone*), with interbanded quartizites and siliceous limestone in the middle..	900
1. Redtop formation..	Quartzites, argillites, volcanic materials, and some limestone..	1,200

In the autumn of 1919 fossils were found for the first time in the vicinity of Hedley. They occurred in an argillaceous limestone and directly above the massive, blue, Sunnyside limestone, the base of the Nickel Plate formation which outcrops on the tramway about 1,200 feet west of Sunnyside No. 2. The fossils were examined by Mr. Kindle of the Geological Survey who furnished the following report on the collection:

"The specimens of echinoderm fragments from the Nickel Plate formation, Hedley, B.C., were referred to Mr. Frank Springer. Mr. Springer under date of December 3 sent the following memo. regarding them: 'The rock-fragment you have sent me, No. 6348, contains some stem ossicles of a species of *Iocrinus* and a radiole of an echnoid like *Cedari.* Neither is well enough preserved for specific

[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877-78, pp. 84-86B.

[2] Camsell, Chas., Geol. Surv., Can., Mem. 2, 1910.

identification, so the horizon cannot be desided from the evidence. Both have a resemblance to Triassic and might belong anywhere from that horizon to the late Jurassic. That is all I can say about them.' I think we may be safe in referring your collection to the Mesozoic although it is not very clear just where in the Mesozoic it belongs."

The above determinations place the Nickel Plate formation in the Triassic or Jurassic and thus the section at Hedley is of the same general horizon as the Nicola series of Dawson[1], the Cultus formation of Daly[2], the Marble Bay formation[3] of Texada island, and the Sutton formation[4] of Vancouver island.

SLOCAN MAP-AREA, B.C.

By M. F. Bancroft.

CONTENTS

INTRODUCTION.

The Slocan district is well known throughout Canada as the principal producer in British Columbia of rich silver-lead ores. The production credited to this district has a realized value of at least $50,000,000.

The Slocan map-area includes the mining centres between Silverton creek on the south and Whitewater basin on the north, with most of the district tributary to Kaslo creek. This creek comprises about 260 square miles, centrally situated in the Selkirk mountains, between Kootenay and Slocan lakes.

The district is reached from the main line of the Canadian Pacific railway by rail and boat via Arrowhead and Nakusp to New Denver, Silverton, and Sandon; by the Crows Nest branch of the same railway via Nelson or Procter; from Nelson by boat to Kaslo; or by rail and boat to Silverton and New Denver via Slocan lake. The Canadian Pacific railway operates the line through the map-area from Rosebery to Kaslo, with a branch from Three Forks or Parapet Junction to Sandon. The district throughout is well supplied with roads and trails, for a mountainous country, and most of the properties not on the railway line may be readily reached by wagon or by saddle horse.

FIELD WORK AND ACKNOWLEDGMENTS.

The season of 1919 was devoted to a study of the surface geology of the eastern half of the Slocan map-area, from Kootenay lake west across the Blue ridge through the roughest part of the area bordering the Lardeau map-sheet. Other geological sections were examined south of Kaslo creek across Kemp mountain and west to Mansfield creek. Mines and prospects were visited in order to note the most recent mining developments in the Kaslo and Sandon districts.

In the field the writer had the able assistance of C. W. Robinson and S. A. Childerhose. The writer is under obligation to the people of the Slocan district for their cordial assistance, especially the mine managers and owners, who gave all the information asked for and extended hospitality at the mines.

1 Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, pt. B, 1896, p. 112B.
2 Daly, R. A., Geol. Surv., Can., Mem. 38, 1912, p. 516.
3 McConnell, R. G., Geol. Surv., Can., Mem. 58, 1914, p. 17.
4 Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912, p. 68.

GENERAL GEOLOGY.

Detailed study of the surface geology of the eastern half of the Slocan map-area during the season of 1919 has made it possible to submit in this report a new geological table of formations, which sums up the writer's conclusions.

Table of Formations.

Quaternary	Recent and Pleistocene		Stream Deposits Glacial deposits
	Great unconformity		
Mesozoic	Upper Jurassic	Basic dykes, Aplite dykes, Nelson granodiorite	Period of long continued deformation and intrusion
	Intrusive contact		
	Jurassic	Kaslo schists	
	Intrusive contact		
	Jurassic	Milford series	
	Disconformity		
Palæozoic	Upper Carboniferous	Slocan series	
	Conformable contact		
	Carboniferous or Pre-Carboniferous	Ainsworth series	

Comparison of the geological record of the Slocan map-area for 1919, with that of 1916, will make clear the fundamental points common to the two tables and at the same time emphasize the new features.

Among the pre-Mesozoic geological series only two groups of mainly sedimentary origin are included, the Ainsworth (Shuswap) and the Slocan series. A conformable contact is emphasized as the structural relation between the two groups, in place of Drysdale's fault contact. A disconformity marks the transition from Palæozoic strata to Mesozoic strata in the case of the Slocan series and the new division, Milford series. McConnell's Kaslo schists (Drysdale's Kaslo volcanic series) follows next in intrusive relations with the Milford and Slocan series.

The fundamental consideration in drawing up the new geological table is the geological horizon represented by the fossiliferous Slocan series. A conformable contact between this series and the Ainsworth series permits a reconsideration of age relations from the oldest to the youngest rocks of the Slocan map-area. This scheme was used in 1917 by the writer in summing up Lardeau geology without reference to a basal series of assumed Pre-Cambrian age.

The fossils obtained in the Slocan in 1919 and reported on by E. M. Kindle furnish local support to the age relations given by Schofield[1] for the divisions of the Ainsworth map-area in 1918. Under the description of the separate rock groups all the age determining factors have been considered.

[1] Schofield, S. J., Geol. Surv., Can., Sum. Rept., 1918, pt. B, p. 60B.

Pre-Mesozoic.

Two groups of rocks, the Ainsworth series and Slocan series, chiefly of sedimentary origin, are considered in this report as part of the pre-Mesozoic geological record in the Slocan.

Ainsworth Series.

Ainsworth series[1] is a local name first used by Schofield in referring to that part of Dawson's Shuswap outcropping along the west shore of Kootenay lake, extending through the Ainsworth map-area and northward into the Slocan map-area. The Ainsworth series consists of mica schists, quartzites, siliceous limestones, thin bands of hornblende schists, and garnetiferous mica schists. The thickness of the series in the Slocan map-area exceeds 10,000 feet; traced northward along the shore of Kootenay lake, the Ainsworth series exposes lower beds than those outcropping at Ainsworth and consequently the series increases in thickness in the Slocan map-area. Since no base is exposed for the Ainsworth series only its upper stratigraphic relations could be examined within the map-area.

The Ainsworth and Slocan series, together locally constitute a conformable series, apparently monoclinal, striking north-northwest with dips to the west varying from 30 to 50 degrees. The several types of rocks composing the Ainsworth series alternate with one another, so that differential weathering produces strike ridges along the steeply east-facing mountain slopes.

The belt of limestone that marks the geological boundary of the Slocan series and Ainsworth series gives rise to strike ridges at a fairly uniform elevation along the mountain slope up from the west side of Kootenay lake. Fossils were found in this limestone across the head of Milford creek in 1919, and where it crosses the Kaslo wagon road in 1916 and south along its outcrop east from Kemp mountain more fossils were found in 1919. This fossiliferous horizon has, therefore, been traced from north to south across the Slocan map-area.

There is much in favour of considering the western boundary of the Ainsworth series as a conformable contact. It is well exposed across the head of Milford creek and in the rocky bed of Falls creek. At the head of Milford creek the contact is distinctly a conformable one, the bedding of both series is sharply defined, and the limestone of the Slocan series rests conformably on hard mica quartzites, both dipping at an angle of 30 degrees westward. In following the contact southward the two series steepen, but both combine to make up a monoclinal structure similar to that of the Ainsworth section. The writer failed to find any evidence for the fault contact postulated by Drysdale in his Slocan structure sections (Map No. 1667). The actual outcrops of the Ainsworth-Slocan series contact along the Blue ridge are few in number and difficult to reach in the field, but regionally and locally field observations point to a conformable succession from the older series to the younger Slocan series. Evidence for strike faulting along this contact is entirely missing in the field. In Drysdale's structure sections the fault is put in as a structural necessity, but the determination that the Kaslo schists are intrusive and not extrusive causes this necessity to disappear.

Accepting the fact that the Ainsworth series conformably underlies the Slocan series, then the older series can for the present be considered as of Carboniferous or pre-Carboniferous age. The principle of an Archæan basal series was bound up in the term Shuswap, hence the use of a local name, the Ainsworth series.

Slocan Series.

The Slocan series consists of argillaceous quartzites, limestones, and slates or argillites with gradational types, all of which are more or less carbonaceous. This series occupies the main area of the map-sheet, south and west of the Kaslo schists.

[1] Schofield, S. J., Geol. Surv., Can., Mem. 117, 1920.

Argillites and quartzites predominate in the western half of the outcrop area, whereas limestone is the more prominent member in the eastern part of the area. The series appears to increase rapidly in thickness westward, from 2,000 feet on the Blue ridge to a maximum of 15,000 (Drysdale's structure sections for 1916) in the western part of the area. It is apparent that the Slocan series[1] "forms an undoubtedly thick series, but the folding, faulting, and lithological similarity prevent any section being made that would represent to a certainty the actual thickness. Local crush zones accompanying faulting are common, but so far as noted the displacements are small."

The Slocan series overlies conformably the Ainsworth series in the eastern part of the Slocan map-area. The lower limit of the Slocan series at present is fixed by a fossiliferous limestone band which rests on dull grey, schistose mica quartzites of the Ainsworth series at the head of Milford and Schroeder creeks. Throughout the Ainsworth, Slocan, and Lardeau map-areas this contact is sharply defined in outcrop. In Drysdale's type section (Map No. 1667) for 1916, along the Schroeder Creek-Davis Creek ridge, the rocks on both sides of the contact are well bedded and the bedding planes almost vertical.

In 1916 the Slocan series was supposed to overlie conformably the Selkirk (Kaslo schist) series and what was thought to be the Niskonlith part of the Selkirk series which rested conformably on the Ainsworth series. Drysdale remapped the Niskonlith[2] of the map-area as Slocan series, on the grounds of lithology and fossils. in order to retain the Kalso schist series as the base of the Slocan series the fault contact was postulated between the Ainsworth (Shuswap) series and the Slocan series. The field evidence obtained in 1919 favours entirely a conformable contact relation between the Slocan series and the Ainsworth series, thus confirming the original views of Dawson, McConnell, and others regarding this contact.

Confirmatory fossil and structural evidence has been accumulating since 1916 regarding the age of the Slocan series. Originally the provisional age given by Dawson was Palæozoic and probably Carboniferous. During the field season of 1910 specimens of plant impressions were found in the black argillites of Reco mountain. The first fossils of marine origin from the rocks of the map-area were found in 1916 and more were collected in 1919. It could be stated definitely in 1916 that the Slocan series was not Pre-Cambrian but post-Cambrian. The weight of fossil evidence now obtained favours an upper Palæozoic age (Carboniferous to Upper Carboniferous) for the group.

The fossils collected in the Slocan map-area during the season 1919 include four lots all representing limestones which have been more or less metamorphosed, thus rendering the fossils difficult to determine. These fossils are all from limestones of the Slocan series and are reported on by E. M. Kindle, as follows:

"Lot No. 1, Kemp mountain. This lot contains numerous crinoid stems and abundant fragments of other fossils too poor for determination. The fossil contents of this lot taken alone afford little evidence regarding the horizon represented. Lot No. 2, however, which is stated by the collector to represent the same horizon, affords more definite evidence, as will be seen.

"Lot No. 2, headwaters of middle fork of Kemp creek. The fossils from this lot include crinoid stems, *Pugnax* sp. undet., *Seminula?* undet., and *Gastrioceras?* cf. *G. kingii*. This fauna cannot be older than upper Devonian nor younger than Triassic. I believe it to be of Carboniferous age—probably Pennsylvania.

"Lot from near Helen Prospect, Blaylock. This lot includes a single fossil, a goniatite which appears to belong to the genus *Gastrioceras* and comparable with *G. kingii*. This is a Carboniferous genus, and the lot is accordingly referred to the Carboniferous.

"Lot from Lincoln prospect, Robb creek near Blaylock, Slocan map sheet. Undeterminable fragments only are represented in this lot."

1 LeRoy, O. E., Geol., Surv., Can., Guide Book No. 9. 1913. p. 98.
2 Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1916, p. 57. (See map No. 1667.)

In addition to the fossils actually collected, the writer noted that crinoidal fragments were abundant in limestone beds, near the head of Milford creek, and also in the main Slocan series outcrop area northwest from Kemp mountain to beyond Whitewater creek.

Mesozoic.

The Mesozoic geological record is considered in this report to include a sedimentary series, Milford series. Jurassic igneous activity is represented by intrusives, Kaslo schists, Nelson granodiorite, and minor intrusions. Hence there was prolonged igneous invasion and crustal readjustments, then a period of mineralization followed giving rise to the rich silver-bearing ores of the Slocan.

Milford Series.

The Milford series embraces argillaceous quartzites and limestone possibly of Mesozoic age, resembling very much the Slocan series. The name was first used by LeRoy in dealing with the rocks included in the Blue ridge or Milford syncline, named after Milford peak of the Blue ridge.

One lot of fossils collected in 1919 served to separate Milford series from Slocan series. E. M. Kindle reports on this lot as follows:

"Lot from heads of Davis and Copper creeks, southern Lardeau mountains: The fossils in this lot consist of fragments of a species of Belemnites. The horizon is believed to be Jurassic."

Along the axial line of the Milford syncline a flinty, quartzite formation stands out in relief, a key to the synclinal structure. The flinty quartzite occurs only in the central part of the Milford synclinal belt and no equivalents of it have been noted in the main area of folded Slocan series to the west. The flinty quartzites vary from dull grey to white and from green to purple shades in colour. These hard, well-bedded quartzites associated with siliceous schists represent a thickness of 500 feet.

If the upper beds of the Blue Ridge syncline are of Jurassic age, then Drysdale's correlations on either side of the flinty quartzites are only partly correct. For the Jurassic fossils collected in 1919 on the Davis Creek slope were obtained a short distance east of the outcrop area of Kaslo schists, where Drysdale's structure section shows a repetition of Carboniferous strata.

The transition from Palæozoic to Mesozoic in the fossiliferous rocks of the Slocan map-area is not marked by any definite characteristic in the field. The new geological division, Milford series of possibly Jurassic age, is adopted in order to retain the term Slocan series in its original Palæozoic significance. The flinty quartzites, once used by the Indians for making arrows, is the distinctive feature of the series, as it occurs on the Blue ridge. The basal members of the Milford series resemble the Slocan series.

The time break between the deposition of the two groups is recorded by a disconformity, occurring at some point below the flinty quartzite strata of the Milford syncline.

Jurassic Igneous Activity.

It is a general principle in geology that during batholithic invasion basic magmas are the first to be intruded.

Kaslo Schists. The Kaslo schist igneous complex illustrates the above principle and it constitutes a batholith, in shape, size, and mode of occurrence, within the Slocan and Lardeau map-areas. This Slocan batholith of basic magma was intruded considerably in advance of the West Kootenay or Nelson batholith which also forms a principal feature of the southern half of the map-area.

The term "Kaslo Schists"[1] was used by R. G. McConnell in 1894 to include the Selkirk rocks (green schists) which outcrop along a part of the Kaslo-Sandon railway. The term Kaslo schists is a local name and to be preferred to the regional term Lower Selkirk series.

On the Slocan geological map the outcrop area of Kaslo schists narrows to the south and does not form one of Schofield's geological units within the Ainsworth map-area; hence the term Kaslo schists as used in this report is restricted to the Slocan map-area, Lardeau map-area, and to a limited area to the south of the sheet.

The Kaslo schists consist of a variety of basic igneous material, including intrusive breccia, serpentine, porphyrites (augite and hornblende), diorite, and gabbro.

A study of the contacts outlining the outcrop area of the Kaslo schists, in 1919, shows that heretofore these contacts had not been definitely located on the Slocan map and their structural relation as intrusive contacts had never been considered. The rocks about the contacts have been altered by heat and pressure. Intrusive breccia is a marked feature along the east contact of the Kaslo schists with the Milford series.

Numerous apophyses of this batholith were injected into the Blue Ridge synclinal belt of rocks of Milford series and Slocan series.

The size of the outcrop area of Kaslo schists is about 25 square miles, within the Slocan map-area, and is of much greater extent in the Lardeau map-area. The shape of the outcrop area is that of a mass elongated parallel to the structural trend of the Ainsworth and Slocan series which strike in a northwest-southeast direction. The maximum width of the outcrop area is about 3 miles; this area underlies most of the drainage basin, east and north of Kaslo creek on the west side of Blue ridge.

North of Blue ridge the east and west contacts form steep side walls, outwardly inclined, suggesting that a roughly dome-shaped body once projected upward covered by a great thickness of folded strata.

The east contact of the Kaslo schists dips steeply eastward near the head of Davis creek and straightens up to the south, showing a slightly reversed dip at the head of Tenmile creek, where it crosses over on to the west side of the summit of Blue ridge. It continues on the west side of the ridge to the head of Falls creek where it again crosses the summit and roughly parallels the shore of Kootenay lake at an elevation above 5,000 feet. At the end of Blue ridge this contact turns abruptly westward, crosses Kaslo creek, and rises again on the east-facing slope of Kemp mountain.

The west contact of the Kaslo schists is not so steep as the east contact and always dips west to southwest.

Both the east and west contacts are crosscutting, though folding may have masked this feature in places.

The east contact traverses the Milford series, cutting across into the limestones of the Slocan series near the head of Falls creek, not extending east into the Ainsworth series, however, as far as the writer observed, though LeRoy[2] notes that the biotite schists of the Shuswap are in sharp contact with the softer green schists of the Selkirk (Kaslo schists). The east contact of the Kaslo schists rises from the bed of Kaslo creek to the summit of Blue ridge, and from this point can be traced northward along the eastern side of the summit. The sedimentary beds east of the Kaslo schist contact on Kaslo creek dip at high angles to the west, and the east contact of the Kaslo schists in passing above also dips westward, but at a much lower angle. This crosscutting relation was hitherto overlooked in Slocan geology.

Near the west contact of the Kaslo schists with the rocks of the Slocan series, the strata dip in places conformably with the contact and in other places the strata near the contact dip steeply eastward towards the intrusive contact, indicating a crosscutting relationship. This is a pronounced feature along the west contact from

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[1] McConnell, R. G., Geol. Surv., Can., vol. VII, 1894, p. 31A; vol. VIII, 1895, p. 24A.

[2] LeRoy, O. E., Geol. Surv., Can., Sum. Rept., 1910, p. 124.

Rossiter creek to Lyle creek. In 1909 it was thought by LeRoy that the crosscutting character of the west contact between the Kaslo schists (Selkirk series) and the Slocan series was due to a thrust fault[1] along the axis of a sharp fold.

Many roof pendants can be seen in traversing Blue ridge, especially south from Falls creek, not far from the east contact of the Kaslo schists and Slocan series. There the Kaslo schists form an escarpment on the east side of the ridge. Among the roof remnants the flinty quartzites of the Milford series are well represented.

Small dykes of green schistose rocks resembling types of the Kaslo schists are fairly numerous in the section across the Blue Ridge synclinal belt of Milford and Slocan series. One dyke, 100 feet in width, was followed southward from Schroeder peak for several miles to the head of Falls creek where the Kaslo schist batholith cuts across to the eastern limb of the syncline. This dyke was found to persistently cut through the flinty quartzites occupying the central part of the Milford syncline and was traced to within a short distance of its junction with the main body of Kaslo schists.

Judging from the shape of the outcrop area of Kaslo schists southward from the summit of Blue ridge, the main mass has here assumed the form of a large apophysis or immense dyke.

The origin of the Kaslo schists furnishes the greenstone problem of the Slocan map-area. When the West Kootenay map was produced this greenstone group was tentatively considered part of "the great, green, predominantly diabase portion of Palæozoic strata of British Columbia," which was, in parts of West Kootenay, known to carry rich ores of economic importance, particularly copper, silver, and gold. Rocks of similar character have been described in many parts of Kootenay district.

The name "Kaslo volcanics" was used for this group by Drysdale in 1916, suggesting an origin through vulcanism. The group was thought to embrace such igneous rock types as tuffs, agglomerates, and intermediate varieties. It was also thought that the group contained intercalations of limestone and other sedimentary rocks. The Kaslo volcanics were represented in Drysdale's structure sections as the old basal series upon which the Slocan series had been deposited.

Possibly some intermediate types of igneous rocks appear in the Kaslo schist series, but to the writer's knowledge no definitely extrusive types belong to the group.

No intercalations or minor developments of sedimentaries that might not be classed as inclusions or roof pendants could be found this season in the Kaslo schist area.

The intrusive breccia noted along the contacts was mistaken for squeezed conglomerate by Drysdale, who assumed an erosional contact between the Kaslo schist series and the Slocan series. The writer found a few, rounded, pebble-like inclusions in a schistose matrix, not at the contacts, but well within the outcrop area of the Kaslo schists. The pebble-like fragments were composed of greenish, siliceous, igneous material in a soft, flaky matrix of the same colour. No such material was noted in the sedimentary series composing the roof rocks of the Kaslo schist batholith

Field facts now available support the view that the Kaslo schists underlie the Milford and Slocan series only to the degree that a batholith may be said to underlie a roof cover. There is evidence to prove that the bulk of rocks outlined in the Slocan area as Kaslo schists are intrusive into the Milford series of Jurassic age, and also into the Slocan series of Upper Carboniferous age.

The Kaslo schist batholith is invaded by the Nelson granodiorite in the Lardeau map-area. It is, therefore, older than the Nelson granodiorite, which is probably upper Jurassic in age.

Nelson Granodiorite. The name Nelson, from the city of Nelson, where it is typically developed, has been given to the enormous batholith covering the major part of the western half of Kootenay district. This granitic mass covers an area exceeding

[1] LeRoy, O. E., Geol. Surv., Can., Sum. Rept., 1909, p 132.

1,000 square miles and only the northern edge appears in the Slocan map-area. Other masses and cupola stocks are found to the north of the main mass in this map-area and in the Lardeau map-area, and are to be considered as extensions of the main batholith and connected with it in depth.

The batholith and outliers are traversed by fissure veins carrying silver-lead and zinc ores. The plutonic rocks making up this batholith are considered to be the source of the silver, lead, and zinc ores.

The rock is usually quite fresh and varies from a straight granite through granodiorite to a quartz diorite. There is no great range in differentiation as regards composition, the main differentiation being one of textures.

There are few isolated areas of roof pendants and inclusions of the once overlying rocks. The contact metamorphism of the wall rocks covers an area of comparatively narrow width, altering the slates to andalusite, hornblende, and mica schists, the quartzites to quartz schists, and the limestones to crystalline types.

At depth, as along Kootenay lake, the metamorphism has been more intense, altering the sedimentaries to the types represented in the Ainsworth series, which is host rock to many minor intrusions of aplite, fine-grained granite, quartz porphyry, and pegmatites.

Minor Intrusives. The minor intrusives of the map-area are considered in this report as the apophyses of the Kaslo schists and Nelson batholiths.

Three sets of dykes in point of age were noted. The oldest dykes are connected with the Kaslo schist invasion. The aplite dykes from the Nelson batholith were followed by complementary basic dykes.

All the dykes of this area have suffered from movements of the enclosing rocks and are folded and faulted.

Period of Mineralization. The ore-bearing fissures of the Slocan, so far as the writer observed, crosscut the youngest basic dykes. This would indicate that after the intrusion of the basic dykes, the consolidation of the Nelson batholith continued with crustal adjustments, during which mineral solutions emanated into shear zones and fissures. Hence the important period of mineralization in the Slocan belongs to the later stages of intrusion of the Nelson batholith of upper Jurassic age.

ECONOMIC GEOLOGY.

Silver-lead and zinc deposits occur in the granitic rocks of the Nelson batholith and to a great extent in the host rocks surrounding the batholith. The Mesozoic period of mineralization is considered responsible for the great number of ore deposits which occur in the pre-Mesozoic rocks of the map-area.

The geological map[1] of the Slocan mining area for 1916 suffices to show the position and wide distribution of the numerous fissure veins which have made such well known mines as the Standard, Surprise, Payne, Queen Bess, Whitewater, Wellington, McAllister, Rambler-Cariboo, Reco, Last Chance, Slocan Sovereign, Noble Five, Galena Farm, Van Roi, Hewitt, Richmond Eureka, Silversmith, Hope-Ruth, Mountain Con, Flint, Cork Province, and many others.

The key to distribution of mineralized areas in the Slocan, as judged from the geological map (No. 1667) seems to rest with the structural relations established at the close of the Jurassic period of igneous activity. The flatly underlying, widespread, irregular contact surfaces of the batholiths which carry relatively shallow embayments of folded Slocan slates, are the best mineralized areas. The ore deposits are most numerous in the Slocan slates above intrusive contacts which slope away gradually and become relatively few and unimportant in the rocks bordering steeply pitching contacts.

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1916, Map No. 1667.

The intrusive contacts of the Nelson batholith in the map-area are of the greatest importance. Genetically connected with this batholith are a great number of sills, dykes, bosses, and stocks.

The numerous small intrusions in the mineralized areas undoubtedly had a marked influence on ore deposition by rendering the slates more resistant and permitting the formation of well-defined fissures and cross-fissures. This genetic association of minor intrusives and ore-bearing fissures is notably a characteristic of ore-bearing ground in the Slocan.

Types of Ore Deposits.

The silver-lead and zinc ores of the Slocan occur generally in fissure veins which in places give rise to replacement deposits in limestone.

Veins. [1] "All transitions exist from the true fissure veins with well-defined walls to fissure zones and shear zones made up of a series of interrupted torsional or crevasse-like fissures, in line or en échelon. The fissure veins and zones may pass into stock works, or a series of connected veins between the hanging and foot-wall fissures."

[2] "The fissure veins are most numerous in the Slocan series where they invariably cut across the strike of the formation; if they coincide in strike they cut across the dip, and terminate usually by either turning suddenly and following a bedding plane or by feathering out in the broader bands of the softer slates. In certain definite areas the fissures form a widely parallel system; the dips range from 40 to 80 degrees and as a rule are well over 50 degrees."

Numerous irregularities appear in the fissure veins of Slocan. The structural planes due to fissuring and jointing in the Slocan series vary much in direction and when slip planes are encountered underground it is difficult to say whether they are of special significance. Many barren fissures are associated with productive fissures. However, in the larger mines one set of structures may be traced from one level to the next or possibly through a series of levels.

Ore-shoots. When it comes to the localization of workable ore-shoots in the fissure veins of the Slocan, few uniform guides exist, each mine presenting different problems. Surface indications may prove quite misleading under the final tests of underground developments.

LeRoy and Drysdale considered cross-fissures from either the foot or hanging-wall side of the vein most favourable factors in the formation of shoots. As a rule the high grade ore favours the hanging-wall side of the vein, though this is not invariably so. Vein intersections are favourable to the formation of Slocan ore-shoots. The carbonaceous argillites and limestones of the Slocan series, because of their composition undoubtedly influenced the precipitation of the ore within the fissure veins of the Slocan. The junctions of productive fissure veins with certain limestone bands have given rise to replacement ore-bodies.

Composite Ore-shoots. The ore-shoots are composite in character and consist of widely parallel bands, lenses and masses of galena and zinc blende alternating with siderite and to a less extent with quartz and calcite. With depth the ore gets poorer and passes into slightly mineralized gangue and crushed rock. The high grade ore-shoots rich in silver carry freibergite as the important silver-bearing ore, and ruby, native silver, and argentite are found in many of the deposits developed along fractures in the more massive ore.

Values in Silver-lead and Zinc. Smelter returns show values of from 10 to 70 per cent lead, 20 to 200 ounces silver, and 2 to 50 per cent zinc to the ton. The common ratio is 1 ounce of silver to 1 per cent of lead, although in some instances the ratio is 2 to 1 and even 10 to 1. The zinc ratio varies from zinc blende contain-

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1916, p. 56.
[2] LeRoy, O. E., Geol. Surv., Can., Guide Book No. 9, pp. 97-100 (1913).

ing only 2 ounces of silver to 50 per cent zinc, up to 1 ounce and more of silver to 1 per cent zinc.

The average values of ore as mined vary from 50 per cent to 75 per cent lead, and from 50 ounces to 150 ounces in silver to the ton. The relative importance of silver, lead, and zinc in Slocan ores may also be judged by the tonnage and metals recovered from the ores of the different mines.

MINING STATUS OF SLOCAN DISTRICT.

Slocan district[1] is credited in 1918 with 47 per cent of the total provincial output of silver, which was 3,498,172 ounces. Seventy-five per cent of the silver mined in British Columbia for 1918 was obtained from the treatment of silver-lead-zinc ores such as the Ainsworth and Slocan mining divisions produce.

The silver values recovered from the Slocan ores are exceptionally good. The productions as given for the Slocan and Ainsworth divisions, year by year, consistently mark the high grade character of the ores produced in the Slocan. In 1918, Slocan division produced 142,700 tons of ore yielding 1,873,236 ounces of silver; Ainsworth division produced 44,937 tons giving 228,699 ounces of silver. The average for the Slocan ore is 13·1 ounces of silver and for the Ainsworth 5·1 ounces of silver to the ton in 1918.

The following list of the largest producers in 1918 is given to illustrate further the character of ores mined.

Standard, Silverton	34,727	tons of ore.
Bosun, Sandon	27,764	" "
Van Roi, Silverton	25,278	" "
Hewitt, Silverton	19,399	" "
Surprise, Sandon	13,998	" "
Rambler-Cariboo, Rambler	7,138	" "
Queen Bess, Sandon	5,314	" "
Galena Farm, Silverton	5,250	" "
Lucky Jim, Zincton	1,724	" "

The tonnage for the individual mines, as given above, indicates considerable variation in the quality of ores produced in each mine at its present stage of development. The largest producer of silver was the Surprise, followed by the Queen Bess. In the lead production the heaviest producer was the Queen Bess, followed by the Surprise, Van Roi, Galena Farm, and Standard. In zinc production the Standard leads, followed by the Surprise, Lucky Jim, and Galena Farm. There were nearly forty shipping mines in the Slocan district and only sixteen mines with a production greater than 100 tons.

FUTURE OF SLOCAN DISTRICT.

Provided market conditions continue to be favourable for the metals produced in the Slocan, the prospects are encouraging both in the Kaslo and Sandon districts. New ground is undergoing exploration in the mines. The Cork Province seems to have much ore in prospect. The Silver Bell is yielding high grade ore. Other developments are in progress on the Silver Bear, Index, Flint, and Martin groups. The belt of Slocan series between the granite of Kemp mountain and that of mount Carlyle constitutes a mineralized area, containing some strong and productive fissure veins and replacements in limestone.

Sandon and vicinity are showing considerable activity. The Silversmith mine developments in depths are proving very satisfactory. The Noble Five has completed plans for a thorough exploration of a large block of ground on the southwest slope of Reco mountain. The new concentrating mills at Alamo and Cody represent in a measure the confidence of operators and owners in future expansion. The Surprise Mining Company is developing the Ivanhoe group and adjoining claims of the Adams group and is also operating the Boston mine near Silverton and the Rosebery mill. The Rambler-Cariboo has purchased new ground.

[1] Robertson, W. F., Ann. Rept. Minister of Mines, B.C., 1919, pp. K 7-26.
Langley, A. G., Ann. Rept. Minister of Mines, B.C., 1919, pp. K 149-183.

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The annual Summary Report of the Geological Survey is now issued in parts, each designated by a letter of the alphabet. Part A contains the report of the Director, reviewing the work of the Geological Survey for the year and containing lists of reports and maps published during the year, and is accompanied by a table of contents for all parts of the annual Summary Report.